elementenergy

Energy Masterplan for the Clonburris Strategic Development Zone

Final report

for

South Dublin County Council

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1 Executive Summary

1.1 Clonburris Strategic Development Zone

On 15th December 2015, the Government approved the designation of lands at Clonburris, as a site for the establishment of a Strategic Development Zone (SDZ). Order 2015 (S.I. No. 604 of 2015) established and extended the designated area for the Clonburris SDZ. A revised Planning Scheme must be made for the designated area not later than two years after the making of the Order. Under the Designation of Strategic Development Zone: Balgaddy – Clonburris, South Dublin County Order 2015, the lands which are deemed to be of economic and social importance to the state, are:

"designated as a site for the establishment of a strategic development zone in accordance with the provisions of Part IX of the Act for residential development and the provision of schools and other educational facilities, commercial activities, including employment office, hotel, leisure and retail facilities, rail infrastructure, emergency services and the provision of community facilities as referred to in Part III of the First Schedule to the Act, including health and childcare services."

The Clonburris SDZ Planning Scheme will represent a shared outlook for the future residential, social, economic and environmental development of a new planned and sustainable community in South Dublin County. The Planning Scheme will be a spatial planning document, led by South Dublin County Council in collaboration with a range of stakeholders including: SDZ landowners, the general public, government agencies and statutory bodies, staff and elected councillors of South Dublin County Council.

At the heart of the holistic approach to the future development of Clonburris are the themes of quality of life, prosperity, sustainability, health and well-being, social inclusion and climate change. The Clonburris SDZ Planning Scheme will provide for a mix of land uses and a range of density areas, making it one of the largest strategic development areas in South Dublin County. As such, it offers significant potential for the development of locally based, low carbon and renewable energy opportunities. This Energy Masterplan represents a strategic first stage in the development of a co-ordinated low carbon energy solution for the area.

The preparation of the SDZ Planning Scheme is currently an iterative process involving a range of stakeholders; this Energy Masterplan has been prepared having regard to the most up to date information as derived from the overarching masterplanning process. The Energy Masterplan will contribute to and be represented in the final Clonburris SDZ Planning Scheme.

1.2 Energy masterplanning approach

A wide range of **energy provision options** available to Clonburris SDZ are presented, including:

- Site-wide and partial **district energy/heat network schemes**;
- **Block-level/community** energy supply;
- **Individual building-level** energy systems.

Energy provision options presented include low carbon and renewable heating and cooling technologies such as air-source, ground-source and water-source **heat pumps**, **biomass** heating and combined heat and power (CHP), **solar thermal**, **gas CHP**, and **solar photovoltaic** renewable electricity generation. The pros and cons of these options – in terms of **economics**, **environmental considerations**, **air quality**, security of supply implications, the **impact on the local electricity grid** and others – are set out in order to highlight the implications of each option for the wider planning process.

Based on the latest emerging preferred scenario for development at the site, an **energy demand mapping exercise** covering the SDZ has been completed, with **sensitivities on the energy efficiency level** of new buildings, including current Part L regulation, the Nearly-Zero Energy Buildings (NZEB) standard, and a higher-still Advanced building efficiency standard. Energy demand data from a number of surrounding areas identified as prospects for an integrated energy network, including Clonburris SDZ, have been collated **using data from SDCC's *Spatial Energy Demand Analysis***.

Through an **economic appraisal**, a detailed comparison of energy provisions options in the particular case of a typical apartment at Clonburris has been undertaken, considering the performance of each option in terms of:

- *Upfront cost to the developer* (likely to be key to considerations of **economic viability**)
- *Lifetime cost to the end-user* (critical to ensure a **low-cost, secure energy supply** to consumers)
- *CO_2 emissions reduction* (to ensure alignment with local and national carbon **emissions reduction targets**)

A range of low carbon energy planning options tailored to **schools** is also presented, and described the advantages and disadvantages of each option in the particular context of schools, including the opportunity for hands-on learning.

Finally, a range of **sustainable transport options** for Clonburris is set out, including provision of services to support sustainable modes of transport, such as car clubs and electric vehicle charging points.

1.3 Key findings

The majority of new build at Clonburris SDZ is expected to be subject to the Nearly Zero Energy Buildings legislation, which will represent a high level of energy efficiency

Based on the latest emerging preferred scenario for development at the site, it is expected that the majority of the development at the SDZ will be constructed during the 2020s. By the end of 2020, and possibly well ahead of this date, all new buildings in Ireland will be required to be constructed to the Nearly Zero Energy Buildings (NZEB) standard. Although the precise details of the NZEB specification are still under development, this will ensure the building are constructed to a high level of thermal efficiency, and with a significant contribution of renewable energy. This analysis, unless otherwise stated, assumes a level of building thermal efficiency consistent with that expected under NZEB.

In the case that the first stage of development at the SDZ occurs before the NZEB standard is a legal requirement, it would be an option for SDCC to 'future-proof' the building construction to a level equivalent to NZEB using enhanced planning policy. It should be noted that the NZEB is likely to entail an increased upfront cost to the building developer, such that the economic viability of this should be considered carefully. While the NZEB standard is still under development, previous work on the possible form of the standard for the Department of the Environment, Community and Local Government[1,2] allows an estimation to be made of the additional cost of meeting the NZEB versus current Part L regulations, which is considered to be in the region of €2,000 for a typical apartment and €3,500 for a typical semi-detached house.

The variation in character across the SDZ means that the most cost-effective low carbon energy provision strategies differ across the site

Based on the review of the emerging preferred scenario for the SDZ planning scheme, as provided by SDCC, combined with the energy demand mapping exercise, it is clear that there is a large variation of the 'character' of the development across the site. In particular, the site includes two hubs of higher density mixed residential and commercial development surrounding the Fonthill and Kishoge trains stations (with the Fonthill hub the higher density of the two) and, with contrasting character, lower density, predominantly residential areas away from the hubs. It is therefore very likely that different energy provision options will be suitable for different parts of the SDZ.

For a heat network to be viable, it must be economically attractive from the perspective of both the end-user and the heat network developer and investors

From the perspective of the end-user, a heat network will be attractive only if the price of heat from the network is less than or equal to the price they would expect to pay for heat using the 'counterfactual' case – likely to be a gas boiler or perhaps electric heating. A fair comparison should include the upfront cost to the end-user and the maintenance costs of the system, as well as the ongoing energy bills; i.e. a lifetime cost comparison should be considered. In addition to the lifetime cost comparison, a comparison of the upfront cost alone is likely to be of interest to the end-user, as a prohibitively high upfront cost is likely to make the option unattractive regardless of the lifetime cost comparison. As such, both of these aspects have been included in the assessment of the viability of a heat network at Clonburris.

In addition, a heat network will only be realised if a developer (along with any additional investors) expect to be able to generate a sufficient internal rate of return (IRR[3]) on the investment through sale of the heat, i.e. if the scheme is sufficiently profitable. The required IRR varies for different investor types and scheme delivery models (see below), but as a rule of thumb a private sector investor is likely to require an expected IRR of at least 10% to invest in a heat network scheme. Public sector bodies, which typically have access to lower cost debt, may be able to provide some or all of the investment, and may apply a lower required IRR; this would allow the developer to charge a lower price of heat to the end-user, thus increasing the likelihood of the scheme being attractive to all stakeholders. As such, our assessment of the viability of a heat network at Clonburris considers the potential IRR the developers/investor could expect to achieve.

If the level of development expected in the Emerging preferred scenario is realised, heat networks at the Fonthill and, potentially, the Kishoge hub would likely be viable

The economic appraisal of heat network options at the SDZ suggests that, if the level of development included in the Emerging preferred scenario is realised, a heat network at each

[1] Department of the Environment, Community and Local Government (DECLG), *Towards Nearly Zero Energy Buildings in Ireland: Planning for 2020 and Beyond* (2012)
[2] AECOM, *Report on the cost-optimal calculations and gap analysis for buildings in Ireland under Directive 2010/31/EU on the energy performance of buildings (recast); Section 1 - Residential buildings* (2013)
[3] See the Glossary for further explanation of terms used.

of the two hubs is likely to be viable – meaning that is would represent good value to the end-user compared with the counterfactual option, and be sufficiently profitable to be attractive to private sector developers.

The analysis shows that a heat network at Fonthill could allow the developer to achieve an IRR of 10% – which is likely to be attractive to the typical private investor – while offering a price of heat to end-users of 8.6 c/kWh if based on Gas CHP. A higher level of CO_2 savings could be achieved for a somewhat higher price of heat using alternative heat supply technologies: at 10.0 c/kWh for a scheme based on biomass heating, and 13.5 c/kWh based on a water-source heat pump (WSHP). A Renewable Heat Incentive (RHI), if offering similar tariffs to those available in the UK RHI scheme, could reduce the required price of heat to 8.4 c/kWh and 9.9 c/kWh for the biomass boiler and WSHP respectively.

The analysis suggests that a price of heat under approximately 14-15 c/kWh represents good value for the end-user in lifetime cost terms as compared with the counterfactual gas boiler heating option. It is important to note that the price of heat includes all upfront, maintenance and ongoing energy costs; i.e. the appropriate point of comparison is not the price of gas to the end-user, but the lifetime cost of the gas boiler option, including the upfront and maintenance costs as well as the gas bills. The relatively high price of the counterfactual heating option is due in part to the high thermal efficiency expected in new buildings built to NZEB standard. A high building thermal efficiency means that the heating system is likely to operate with a relatively low load factor (i.e. low usage), resulting in a higher lifetime cost of heat (in c/kWh) than for a boiler in a typical, less thermally-efficient dwelling, which would see a higher level of usage.

Furthermore, the upfront cost of the heat network option from the end-user perspective is similar to that for the gas boiler case, since the cost of the required building-level equipment comprising the heat interface unit and heat meter is similar to the avoided cost of a gas boiler and gas meter. This means that the user should not experience higher costs either upfront or over the lifetime of the system.

At Kishoge, a heat network achieving an IRR of 10% is likely to require a ≈20% higher price of heat than at Fonthill, at 10.4 c/kWh for the Gas CHP option and 12.0 c/kWh for the WSHP option with RHI. This is due to the lower level of commercial development at Kishoge compared with Fonthill, which reduces the heat density of the site and hence the suitability of the site for a heat network. Nonetheless, for the reasons described above, even at 12 c/kWh our analysis suggests that this may remain the most cost-effective option for new build apartments at Kishoge.

Under the development assumptions made in the Emerging preferred scenario, a viable heat network at each hub could serve around 650 residential apartments in each case, along with more than 35,000 m^2 of non-domestic development at Fonthill and 12,500 m^2 at Kishoge.

An on-site energy centre is currently the most cost-effective solution, as the nearest potential sources of waste heat are not close enough to justify integration

The potential to supply a heat network at one or both of the two hubs using waste heat from existing commercial and industrial sources in the vicinity of the SDZ, has been examined. In particular, the commercial users at Grange Castle Business Park have an energy demand many times that expected at the Kishoge hub. Much of this energy could be recoverable, particularly in the form of cooling water from the data centres or primary processes on site, and could be used as the heat source for a WSHP.

However, even for a lower bound estimate of the required heat distribution infrastructure to link Grange Castle with a heat network at Kishoge – of 1.2 km – the required price of heat to achieve a commercially attractive network is slightly higher than for an on-site WSHP, at 13 c/kWh for the waste heat option versus 12 c/kWh for the onsite energy centre, when the RHI is applied in both cases. Since 1.2 km is the lower bound estimate for the infrastructure link, the required price of heat is likely to be higher than 13 c/kWh. As such, it is concluded that an on-site energy centre is likely to be the more cost-effective option.

If a heat network cannot be realised at the hubs, the next most cost-effective low carbon solution for the residential apartments there would entail block-level heating using biomass or ground-source heat pumps

Under the Emerging preferred scenario, a heat network is expected to be the most cost-effective option for residential apartments located at the hubs. However, if a heat network is not realised (for example, if the level of development realised is significantly lower than assumed here), the next most cost-effective low carbon solution for the residential apartments would be block-level heating based on biomass or ground-source heat pumps (GSHPs).

For these technologies, both the upfront cost and lifetime cost are somewhat higher than for the individual gas boiler counterfactual – for block-level biomass heating, the upfront cost is expected to be around €2,000 higher per apartment than for gas boilers, and the lifetime cost around €1,000 higher per apartment. However, the biomass heating option leads to an additional 7 tonnes of CO_2 savings per apartment than the gas boiler option over the system lifetime.

Given the additional upfront and lifetime cost associated with the low carbon options, however, these are only likely to be realised through additional intervention – for example, through the application of planning policy requiring greater CO_2 savings than stipulated by national building standards.

In addition, while being a cost-effective low carbon option, biomass heating brings several disadvantages, including the risk of air quality issues, noise and disruption associated with biomass fuel deliveries and a greater visual impact than gas heating or heat pumps. These drawbacks should be weighed up carefully against the economic advantages of biomass heating.

Outside the hubs, a heat network is unlikely to be viable

The viability of a heat network incorporating both the Fonthill and Kishoge hubs, as well as the corridor of lower density residential development between the hubs, has been examined. Under the Emerging preferred development scenario, this would be likely to incorporate an additional 2,600 homes. The analysis suggests that a commercially attractive heat network covering this part of the SDZ would require a very high price of heat of 24 c/kWh for the Gas CHP case, and higher for the low carbon options. As described above, this is very unlikely to represent a cost-effective outcome for the end-user.

The analysis of an 'Enhanced development' scenario estimates that in order for the Kishoge and Fonthill scheme incorporating the lower density residential development to become potentially viable, more than ≈120,000 m^2 additional of non-domestic development within the existing scheme boundary would be required to connect to the network. Given that this is more than twice as large as the quantum of non-domestic development at the Fonthill and Kishoge hubs combined in the Emerging preferred scenario (≈50,000 m^2), this is unlikely to be realised. This figure represents a high-level estimate, since the activity type of the potential additional development is undefined (here a typical non-domestic building energy benchmark is applied), but serves to illustrate the low likelihood of a network covering the lower density residential areas of the SDZ being viable.

A range of potential delivery models for a heat network at Clonburris have been described, including models led by the private sector, the public sector or through a joint venture

The required upfront investment for a heat network scheme at Fonthill would be in the region of €3-5 million, depending on the heat supply technology employed. There are a range of delivery models and financing structures which could be used to unlock the required investment. If the level of development expected in the Emerging preferred scenario is realised, the analysis suggests that the heat network scheme could be attractive to a private sector developer; accordingly, an energy service company (ESCO) or utility (or consortium) may undertake to design, build, finance and operate the heat network. In this case, there will be a critical role for SDCC to influence developers, landlords and tenants to connect to the network, and to use planning policy where possible to encourage connection. The Council may also be a heat customer, ensuring Council-controlled buildings are connected where viable. However, in this case SDCC would not have direct involvement in establishing the network.

Alternatively, SDCC could be more directly involved by, for example, providing project finance to the developer, or even participating in a joint venture with an ESCO or consortium to deliver the project. In either case, the provision of low-cost debt finance by the public sector could be key to achieving a viable scheme. It may be possible to obtain funding from wider sources; while there is currently no capital funding scheme in Ireland targeted specifically at the support of heat networks, capital could be available from sources such as the European Regional Development Fund.

The potential delivery models for a heat network at Clonburris are described further in Section 13.

For the lower density residential development, lower carbon heating options are more costly and gas heating remains the most cost-effective option unless the RHI is available

In the case of the semi-detached and detached housing, low carbon energy supply is likely to require a somewhat higher cost premium, as the heat supply strategy cannot take advantage of the economies of scale associated with block-level biomass or GSHP heating.

For a typical semi-detached home, the additional upfront cost for an air-source heat pump (ASHP) versus a gas boiler is in the region of €6,000. For a GSHP, the additional upfront cost is in the region of €16,000. Where no RHI is available, this leads to additional lifetime costs of €8,000 in the case of the ASHP, and €10,000 in the case of the GSHP.

Where the RHI is available, however, the lifetime cost of the heat pump options becomes comparable with that of the gas boiler counterfactual. The ASHP option leads to an additional 6 tonnes of lifetime CO_2 savings per house, and the GSHP option an additional 9 tonnes.

Planning policy is a powerful tool through which the Council's overarching objectives and priorities can be realised

Realising the energy project opportunities described in this masterplanning study is likely to require an update to the planning framework used by SDCC to grant permission for new developments.

Of particular relevance to the projects described here, planning policy could be applied, and may be necessary, to achieve the following:

- **Ensuring building fabric efficiency standards go beyond existing regulations**. While the majority of the development is expected to occur after 2020, once the Nearly Zero Energy Buildings (NZEB) legislation must be in place, the first phase of development may occur before this. Planning policy could be used to ensure the first phase of development is designed to the NZEB level, future-proofing the efficiency of the buildings to avoid the lock-in of higher energy demand.
- **Ensuring developers of new buildings connect to a local heat network**. Tailored, robust planning policy is likely to be critical to the successful delivery of a heat network at Clonburris. In particular, this will be important to ensure the connection of all new buildings to the network where economically viable, placing the burden of proof on the building developer to demonstrate the non-viability of connecting to the network. Without planning policy to support this, there is a risk of the developer opting for an alternative option which can satisfy the building regulations.

2 Introduction

Element Energy were commissioned by South Dublin County Council to develop an energy masterplan for the Clonburris Strategic Development Zone (SDZ) and surrounding areas, including an assessment of a range of low carbon, renewable and decentralised energy opportunities.

The Government's designation of Clonburris as an SDZ indicates its national economic and social significance, and allows development of the site to be fast-tracked following the adoption of a comprehensive and integrated planning scheme. The Clonburris SDZ is a 280 hectare, largely greenfield site, which will become a new sustainable community of Dublin, including extensive residential development, a range of community, leisure and retail services and new employment space.

The key objectives of this energy masterplanning study are to:

- Provide an **over-arching energy strategy** for the site and **identify discrete project opportunities**;
- Consider the site as a **stand-alone** community in the first instance, but also consider opportunities for **integration with neighbouring developments**;
- Demonstrate best practice and a **future proof** design, while taking account of crucial **economic viability** factors;
- Clearly illustrate the development of an **evidence base** and analysis of the energy provision options from which planning policy can be updated, and against which future planning applications can be assessed;
- Demonstrate the innovative use of an energy master planning process as an **exemplar for other developments** in Ireland.

This masterplan aims to future-proof SDCC's planning and energy policy in light of the potential future impact of national and European legislation such as that described in the next section. A key objective of this initiative is to continue to develop the evidence base available to SDCC to allow planners, Council staff and other local stakeholders to make more informed policy decisions relating to energy provision in South Dublin. It is also hoped that the work will act as an exemplar for other local authorities to demonstrate the value of the energy masterplanning process, to encourage similar initiatives elsewhere.

3 Policy context

3.1 National policy and European Directives

As required by the EU's Renewable Energy Directive, Ireland has developed a National Renewable Energy Action Plan (NREAP), which presents Ireland's plans to deliver 16% of its non-Emissions Trading Scheme (non-ETS) energy demand from renewable sources by 2020. This has been translated into sector-level targets, with 40% of electricity to be generated from renewable sources, 12% of heat and 10% of transport energy. Similarly, in response to the EU's Energy Efficiency Directive, the latest National Energy Efficiency Action Plan (NEEAP 3) describes Ireland's plans to achieve a 20% reduction in primary energy demand to 2020. SDCC's SEAP and SEDA initiatives, and now this energy masterplan, aim to fulfil the goals of the NREAP and NEEAP by kick-starting renewable energy and energy efficiency across South Dublin.

The EU Energy Performance in Buildings Directive (EPBD) legislation is also of high relevance to the current work. For example, the EPBD Article 9 requires all new buildings to be "nearly zero energy" by end of 2020. This will require an update to Ireland's current Part L building regulations, as described in more detail in Section 6.4, and will have important implications for the energy provision strategy at Clonburris SDZ.

3.2 Regional and local policy

South Dublin County Council (SDCC) has been involved in the EU Intelligent Energy Europe-funded *Leadership for Energy and Action Planning* (LEAP) project, which aimed to increase the ability of local authorities to drive the implementation of sustainable energy measures using evidence-based processes. As part of this process, the Council developed its *Sustainable Energy Action Plan* (SEAP). The SEAP developed a detailed picture of energy consumption across all sectors in South Dublin, set energy reduction targets to 2020 and established a range of sector-specific actions to reach the targets. The Council has also worked with the Irish Planning Institute on the *Energy for Communities in All Landscapes* (SPECIAL) project, which aims to create higher levels of integration between planning and energy at a local level.

The *South Dublin County Council Development Plan 2016-2022* sets out the Council's objectives for Energy and Transport & Mobility, and reiterates the Council commitment to a proactive approach to identifying and implementing renewable energy and energy efficiency opportunities in South Dublin.

The *Development Plan* was informed by South Dublin County Council's *Spatial Energy Demand Analysis* (SEDA), carried out in partnership with City of Dublin Energy Management Agency (CODEMA). The SEDA is an extensive survey and analysis of the energy demand in South Dublin that aims to enhance understanding of energy demand and provision across sectors and geographical locations. The SEDA has also provided a valuable resource for this current energy masterplanning study.

4 Clonburris SDZ masterplanning

4.1 Overview of Clonburris SDZ

The new SDZ order for Clonburris, published in December 2015, designates Clonburris as a site for:

"…residential development and the provision of schools and other educational facilities, commercial activities, including employment office, hotel, leisure and retail facilities, rail infrastructure, emergency services and the provision of community facilities, including health and childcare services".

In particular, the order notes the deficiency in the supply of housing in the Greater Dublin Area, and places an emphasis on the need for the SDZ to address this deficiency. Taken together, this suggests that the Clonburris SDZ is likely to be largely residential in character, but with a significant element of commercial development, both in terms of employment and services to support the local residential and employment community, as well as substantial provision of public services.

As part of the 2015 SDZ order, the boundary area for Clonburris SDZ was extended towards the west. The current SDZ boundary is shown in Figure 1. The boundary covers approximately 280 hectares of a largely greenfield area. It extends to the south to include a large stretch of the Grand Canal; slightly to the east of the Fonthill Rd (R113); to the R120 to the west; and to the north roughly to the Ninth Lock Rd, extending beyond this to Balgaddy Rd and Griffeen Avenue in places. The site includes the Kildare Rail Link, and will incorporate two railway stations: Clondalkin Fonthill (which is already in operation) and Kishoge (which is not yet in operation). The site also includes a stretch of the Outer Ring Road (R136), running north to south approximately through the centre of the site at the location of the Kishoge station.

South Dublin County Council is currently in the process of developing an updated Planning Scheme for the SDZ. As part of this process, a range of consultants have been appointed to address various aspects of the masterplanning process, including urban design, strategic environmental assessment, traffic and transport, economic viability, flood risk, appropriate assessment, as well as energy, which this study addresses.

Given that there is an ongoing iterative process for the preparation of the SDZ Planning Scheme, this report reflects the most up to date 'Emerging preferred scenario' information at the time of writing. As such an 'Enhanced development scenario' has been examined to explore how a potentially higher level of development on the site could change the viability of a heat network on the site or present the opportunity for an expanded network.

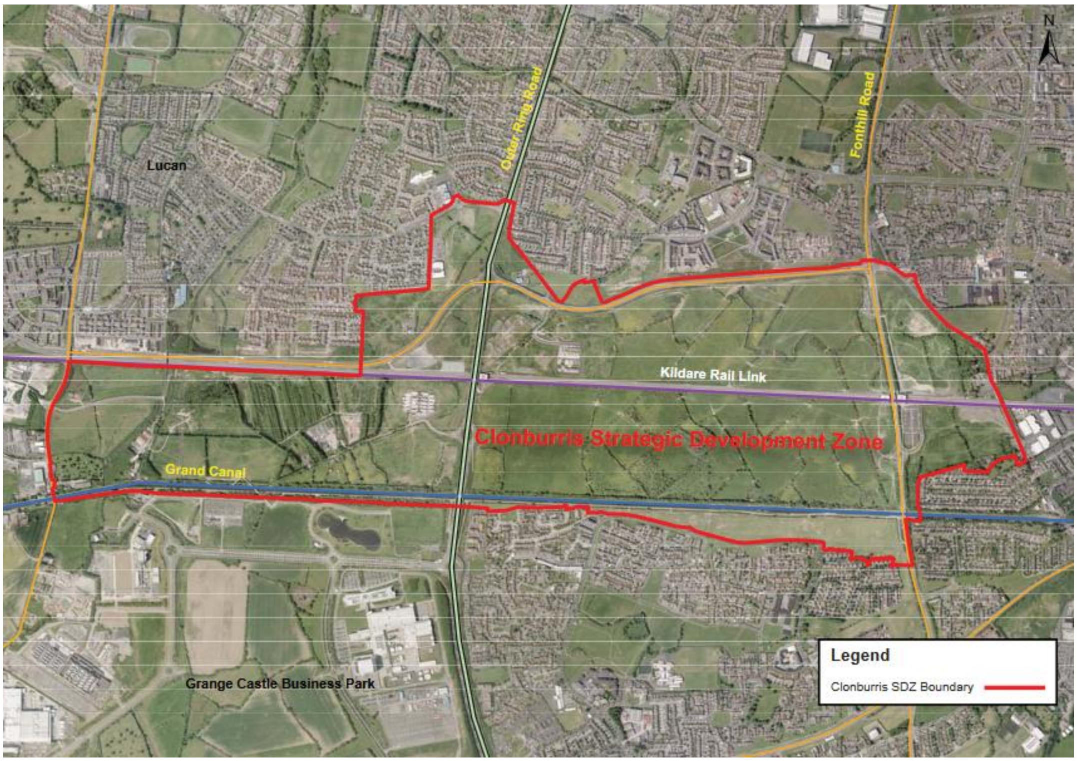

Figure 1: Boundary of Clonburris SDZ

4.2 Emerging preferred development scenario

Development quantum in the Emerging preferred scenario

The Emerging preferred scenario for the Clonburris SDZ development describes a 'bi-centric' development, which envisages two centres or hubs of high density built around the Fonthill and Kishoge railway stations. Of the two hubs, the Fonthill hub has significantly higher density than the Kishoge hub, and is the location of the majority of the retail and employment space. This scenario is illustrated schematically in Figure 3 on page 20.

The information received from SDCC on the development quantum for the Emerging preferred scenario is summarised below.

In the case of the non-domestic development, the quantum is defined with reference to the Fonthill and Kishoge hubs, and to the rest of the SDZ. Table 1 shows the available information on the employment/office development on the SDZ; it is expected that there will be 30,000 m^2 of employment space at full build-out, with 20,000 m^2 of this in the vicinity of Fonthill, and the remainder in the vicinity of Kishoge.

Table 2 shows the corresponding information for the retail development. While some retail space is expected at both hubs, it is clear that Fonthill will form the main centre of retail on the site, with more than 16,000 m^2 of convenience retail, comparison retail and retail services. The emerging preferred scenario suggests that Fonthill will include at least one supermarket.

Table 3 describes the community building uses proposed across the site. The Fonthill hub is expected to include around 2,500 m^2 of community floorspace, which might take the form of a single building with multiple uses as noted in the table. A further community hub will be located at one of the regional parks; for the purposes of the energy masterplanning associated with this study, it is assumed that Kishoge will not include community floorspace. It should be noted that in the context of the final planning scheme, this may be subject to change.

Table 1: Employment/office quantum for Emerging preferred scenario

Centre	Total employment/office (sqm)
Fonthill	20,000
Kishoge	10,000
Rest of SDZ	-
Total	**30,000**

Table 2: Retail quantum for Emerging preferred scenario

Centre	Convenience retail		Comparison retail		Retail services	Total retail
	net sqm	gross sqm	net sqm	gross sqm	gross sqm	gross sqm
Fonthill	3,500	5,303	4,500	6,818	4,000	16,121
Kishoge	1,000	1,515	200	303	1,000	2,815
Rest of SDZ	1,000	1,515	-	-	1,000	2,515
Total	**5,500**	**8,333**	**4,700**	**7,121**	**6,000**	**21,455**

Table 3: Community quantum for Emerging preferred scenario

Centre	Total community floorspace (sqm)	Description
Fonthill (Urban hub)	2,500	Intensive community uses that do not require extensive outdoor space, perhaps including community offices, health centres, nurseries, creches, local shops and high density schools.
Park hub	1,500	Located at one of the regional parks, the park hub will be the main location for community uses that require significant external space. This might be shared with schools and include meetings rooms, sports halls, playground and flexible community space.
Rest of SDZ	11,000	Located on various flexible sites, this would include health centres, childcare, emergency services, places of worship and library space, and others.
Total	**15,000**	

Table 4 presents the proposed residential development for the Emerging preferred scenario. It should be noted that this table reflects the most up to date data from the emerging preferred scenario, and that these data are used for the purposes of this energy masterplanning study only. In this case, the development is made with reference to nine land parcels across the site, as shown in Figure 2 on page 19. It can be seen that the higher density residential development is generally found towards the east of the site.

The emerging preferred scenario suggests that the dwelling mix will be approximately 70% houses and 30% apartments, with the apartments predominantly within 500 m of the train stations, and the Fonthill hub in particular. The apartments would generally be co-located with the high density non-domestic development. Further from the hubs, the residential development is expected to be lower density in character, comprising mainly terraced, semi-detached and detached housing.

Table 4: Residential quantum for Emerging preferred scenario

Land parcel	Net development area (ha.)	Number of dwellings	Dwellings per hectare (DPH)
North west	17.4	855	49
South west	22.0	1030	47
North A	18.4	872	47
South A	17.8	889	50
North B	24.2	1272	53
South B	33.4	1770	53
North east	9.4	583	62
South east	9.6	586	61
Adamstown	14.6	511	35
Total	**166.8**	**8,368**	**50**

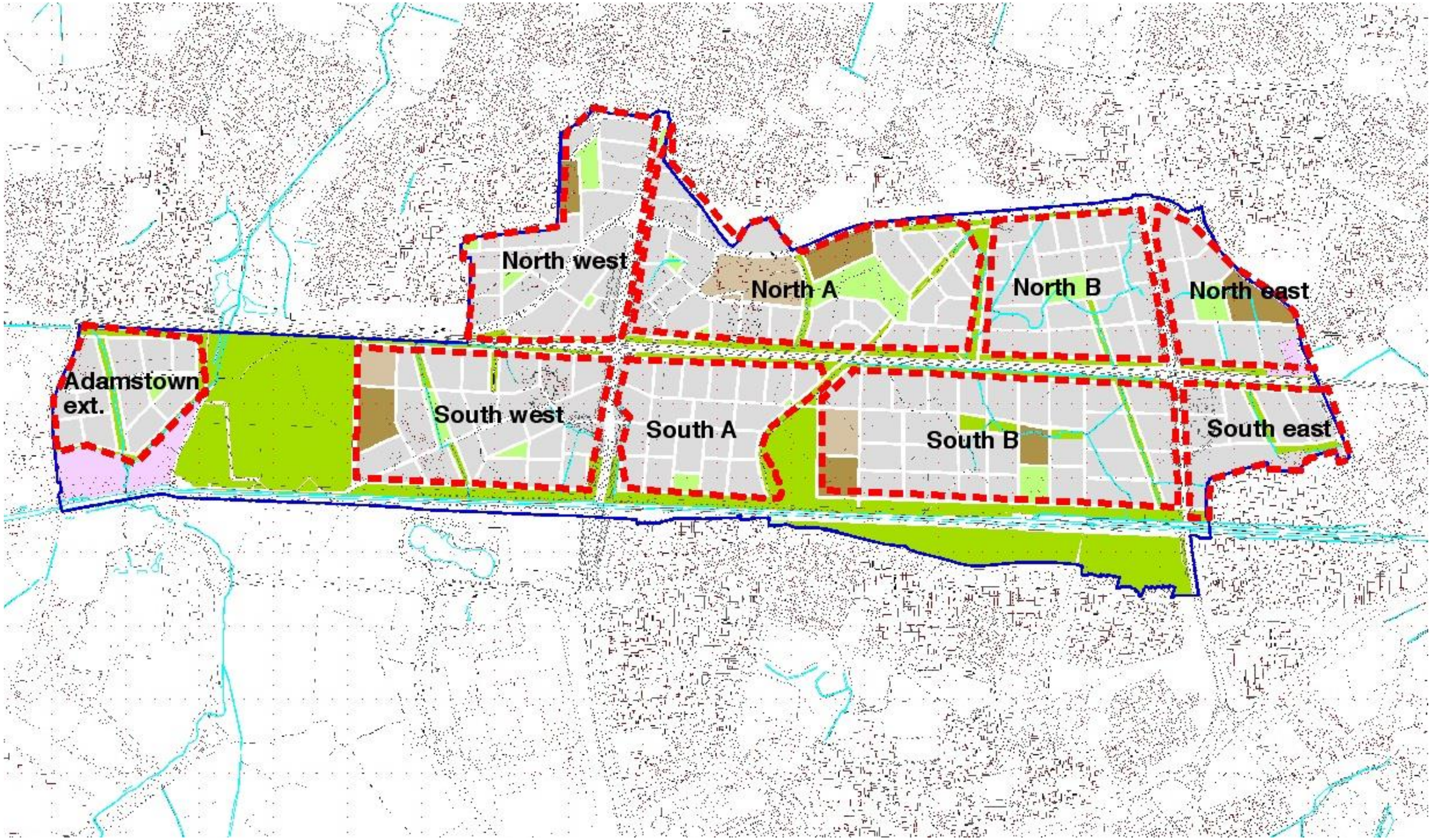

Figure 2: Land parcels used to define residential development quantum

Higher density 'clusters' of development and relevance to heat network

From the information presented above, it is clear that there will be clusters of higher density development surrounding Fonthill and Kishoge hubs, and the Fonthill hub in particular. This is of high relevance for the heat network opportunity analysis, as such clusters present the best opportunity for a viable network.

In order to inform the heat network opportunity analysis, assumptions on the spatial distribution of the development surrounding the hubs have been developed, to define two clusters of higher density development at Fonthill and Kishoge, with the Fonthill hub being the higher density and containing a significantly larger amount of non-domestic floorspace. This is illustrated schematically in Figure 3. This information has been used in the energy mapping exercise described in Section 7, in order to build the best picture of the level and distribution of energy demand at the clusters and across the site.

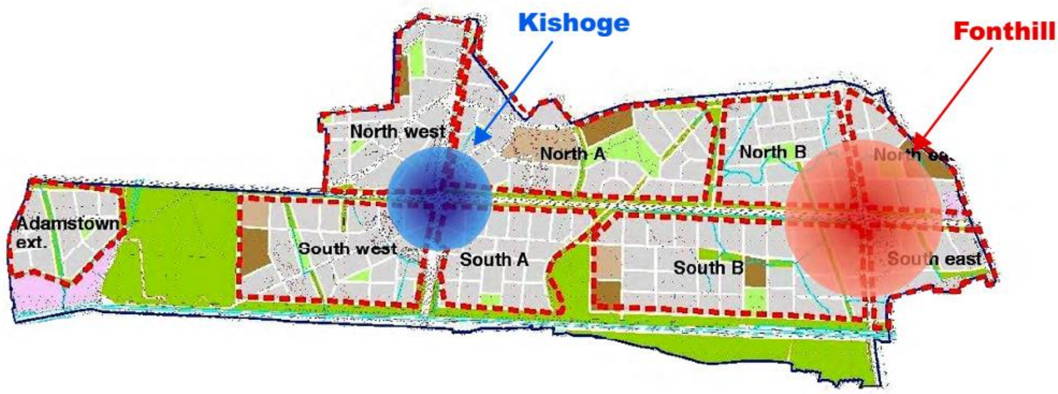

Figure 3: Indication of the development centres in the 'bi-centric' scenario[4]. The Fonthill cluster is shown with a red bubble, and the Kishoge cluster with a blue bubble; the size of the bubbles is illustrative only and intended to represent the higher density and size of the Fonthill hub.

Indicative phasing

The phasing of the development is to be determined in line with the iterative process associated with the emerging preferred scenario. However, on the basis of the best available information, SDCC has proposed the following unit phasing for the purposes of this energy masterplan, defined in terms of the residential and retail development. The phasing plan describes the build out in Phase 1a of two local centres, not including the two hubs, followed by the build-out of the Kishoge hub during Phase 1b by approximately 2023. The build-out of the Fonthill hub is not expected until Phase 3, by approximately 2029. It is important to note that these assumptions are used for the purposes of this energy masterplanning study only.

[4] Based on: South Dublin County Council, *Clonburris Emerging Preferred Scenario Outline Description* (August 2016). Annotated by Element Energy.

Table 5: Residential and retail development phasing in the Emerging preferred scenario

Phase	Year	Description	Residential units	Retail (m^2)
Phase 1a	2017-2020	2 x level 5 local centres	0-1,000	1,258
Phase 1b	2020-2023	Kishoge Level 4 centre	1,001-2,000	2,818
Phase 2	2023-2026	1 x Level 5 local centre	2,001-4,000	629
Phase 3	2026-2029	Fonthill Level 3 centre	4,001-6,000	16,121
Phase 4	2029-2032	1 x Level 5 local centre	6,001-8,368	629
			8,368	**21,455**

4.3 Enhanced development scenario

As a sensitivity to the analysis of the viability of different heat network options on the SDZ, an ‘Enhanced development’ scenario is explored. In this case, the additional quantum of development which would be required to make an impact on the viability of the heat network option in question is considered. This is described further in Section 8.3.

5 Value of previous energy mapping work by SDCC & CODEMA

As part of this energy masterplanning study, effective use of SDCC's *South Dublin Spatial Energy Demand Analysis (SEDA)*[5] has been made. The SEDA comprises an extensive energy demand mapping exercise covering all existing buildings in South Dublin carried out by SDCC and CODEMA in 2015. Figure 4 on page 23 presents a map from this report, showing the energy use and location of each commercial and municipal building in South Dublin; a black star indicates the location of Clonburris SDZ.

SDCC were able to provide the underlying data for use in this work. Table 6 presents an excerpt of this dataset, indicating the key items of data which were used. This includes the location of the majority of commercial and industrial facilities in South Dublin and the associated building area (taken largely from Valuation Office data) and estimates of the heat and electricity demand based on a detailed benchmarking exercise as described in the *SEDA* report.

Although the focus of this energy masterplanning work is on the new development at Clonburris, this data was of great value in identifying opportunities for the SDZ's energy infrastructure to integrate with the surrounding area.

In particular, it was possible to use the data to identify large commercial and industrial users of heat and electricity demand which could, in theory, provide a source of heat to integrate into an energy network on the SDZ. An examination of the map in Figure 4 highlights a number of such large users (shown with red, orange or yellow dots as per the map key) clustered to the south and east of the SDZ. These clusters correspond to three industrial parks in the vicinity of the SDZ:

- Grange Castle Business Park;
- Clondalkin Industrial Estate;
- Western Industrial Estate.

This dataset has thus allowed an initial assessment of the viability of supplying a heat network at Clonburris using waste heat from existing industrial users, to be undertaken. This analysis is presented in section 8.

[5] South Dublin County Council/Codema, *South Dublin Spatial Energy Demand Analysis* (2015)

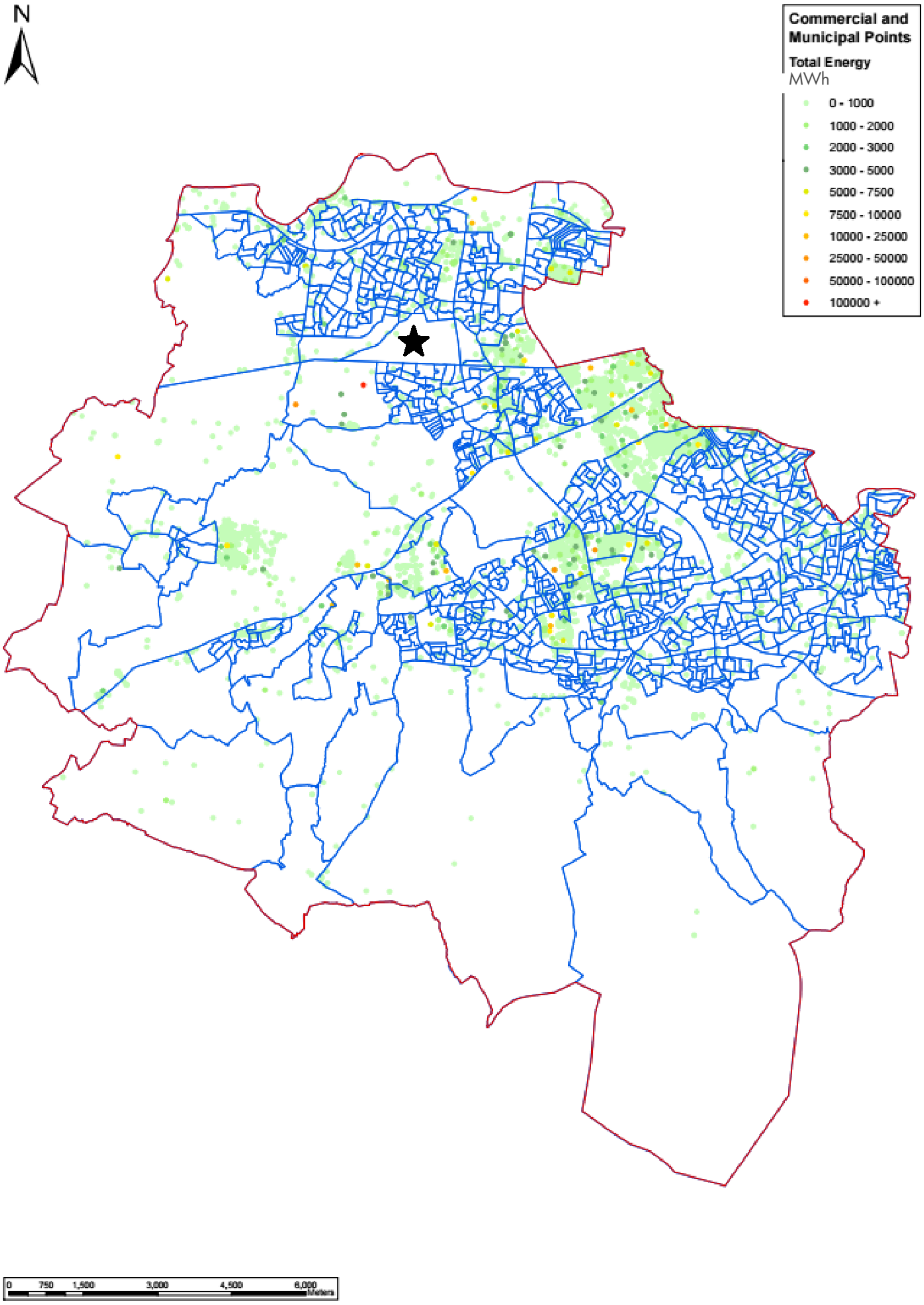

Figure 4: Energy use (MWh) of commercial and municipal buildings in South Dublin (taken from the *South Dublin Spatial Energy Demand Analysis*[6]). The black star has been added by Element Energy and indicates the location of the SDZ.

[6] South Dublin County Council/Codema, *South Dublin Spatial Energy Demand Analysis* (2015)

Table 6: Extract from SDCC's *South Dublin Spatial Energy Demand Analysis* showing subset of the available data

X	Y	Category	PU	DED	Building area (m^2)	Heat demand (kWh/yr)	Electricity demand (kWh/yr)
704187	731796	INDUSTRIAL USES	PHARMACEUTICAL	CLONDALKIN DUNAWLEY	92,523	61,897,820	51,727,703
703805	731196	INDUSTRIAL USES	WAREHOUSE	CLONDALKIN DUNAWLEY	22,169	3,547,006	775,908
703751	731001	INDUSTRIAL USES	WAREHOUSE	CLONDALKIN DUNAWLEY	19,594	3,135,011	685,784
707063	732654	INDUSTRIAL USES	FACTORY	CLONDALKIN MOOREFIELD	4,821	1,581,288	1,568,946
703738	731611	INDUSTRIAL USES	FACTORY (PHARMACEUTICAL)	CLONDALKIN DUNAWLEY	2,815	1,883,375	1,573,928
707063	732654	INDUSTRIAL USES	FACTORY	CLONDALKIN MOOREFIELD	4,779	1,567,512	1,555,278
706990	732520	INDUSTRIAL USES	FACTORY	CLONDALKIN MOOREFIELD	3,523	1,155,659	1,146,639
707054	732771	INDUSTRIAL USES	WAREHOUSE	CLONDALKIN MOOREFIELD	16,062	2,569,944	562,175
703397	733039	INDUSTRIAL USES	FACTORY	LUCAN-ESKER	2,898	950,639	943,220
703911	731019	INDUSTRIAL USES	WAREHOUSE	CLONDALKIN DUNAWLEY	4,307	689,174	150,757

6 Energy provision options for Clonburris SDZ

6.1 Integrated and localised energy provision options

The key focus of this energy masterplan is to describe and appraise a range of options for provision of energy – including heating, cooling and electricity – to the consumers within the development.

At a high level, the energy provision options available to the site (and to different parts of the site) can be described in terms of a spectrum ranging from more 'integrated', such as a **site-wide heat network** or district energy scheme, to more 'localised', such as **block-level** or **individual building-level energy supply**. Whether the more integrated or more localised energy supply option is most suitable for the site depends on the balance between two overarching factors. This is illustrated in Figure 5 on page 26.

The first factor is the **economy of scale benefit** of greater integration. The higher the level of integration of the users on the site, through a network, the greater the benefits of economies of scale and ***diversity***. Energy supply plant must be sized in order to meet the peak demands of the downstream energy users. For individual building energy supply, this means each unit (e.g. boiler or heat pump) must be sized to the full peak of a single user. Within a network, however, the diversity of the many downstream energy users – reflecting the fact that energy is used at different times by different users – means that the aggregated peak energy demand is typically several times smaller than the sum of the individual peak demand for each user. As such, a smaller amount of plant (e.g. in kW) needs to be installed in the network case, leading to cost savings. Furthermore, large plant tends to be less costly on a € per kW basis, leading to further economies of scale for the network option.

The second factor is the **infrastructure cost** penalty of greater integration. The higher the level of integration of users on the site, the higher the cost of the network infrastructure required to connect the users to the heat supply plant and to each other. Individual building energy supply options may require no infrastructure outside each building; a site-wide heat network may require a large amount of underground pipework and heat transfer infrastructure. An intermediate option is block-level community energy supply, whereby a single block (typically a block of apartments, or perhaps a shopping centre or other group of buildings) has a shared heat supply, but is not integrated with other blocks. In this case, infrastructure is required to transfer heat to individual users within the block, but no external underground pipework; however, the benefits from economies of scale are less pronounced than for a wider heat network.

Given the above description, it can be expected that the higher the density of the site, and the more diverse the energy demand, the more suitable the site will be for a heat network, since this allows the greatest economies of scale for the least extensive infrastructure. This simplified picture is a useful framework in which to understand the cases for and against integration of energy users in a heat network. In reality, however, a wide range of additional factors influence the relative suitability of the heat network, block-level and building-level provision options. These factors are described in more detail in Section 8.1, and a quantitative comparison of these options for Clonburris SDZ is presented in Section 9.

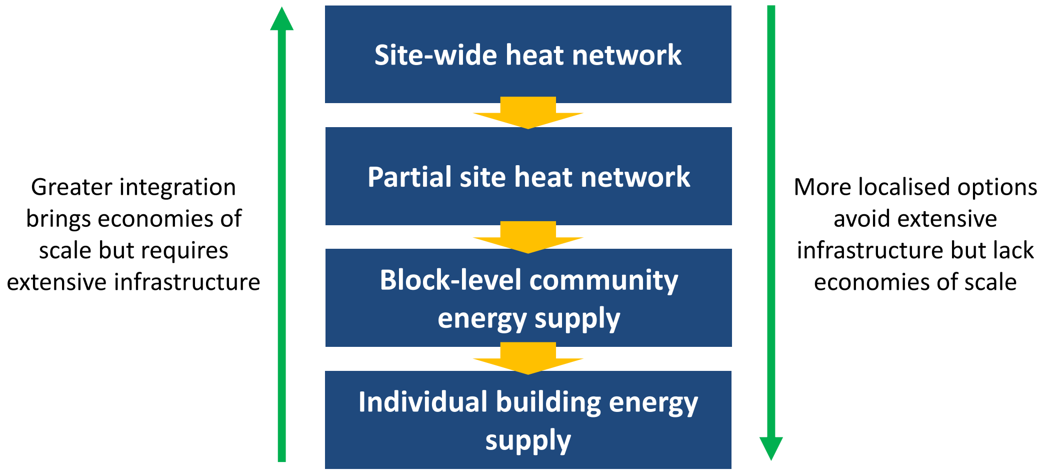

Figure 5: Illustration of possible energy provision options for Clonburris SDZ

6.2 Heat network

Heat networks, also known as *district heat* or *district energy* schemes, are an approach to supplying heat (and potentially also electricity and cooling) whereby the heat is generated at one or several central points and then distributed via pipes to multiple buildings or even whole towns and cities.

Heat networks are common in many countries; 58% of all households in Denmark, and 16% of households in Germany, are served by a heat network. In comparison, district heating in Ireland makes up less than 1% of the heat market. A recent report by Codema and BioXL, however, points to a number of examples of viable existing and planned district heating networks of various forms in Ireland, and suggests there would be potential for an increase in such schemes[7].

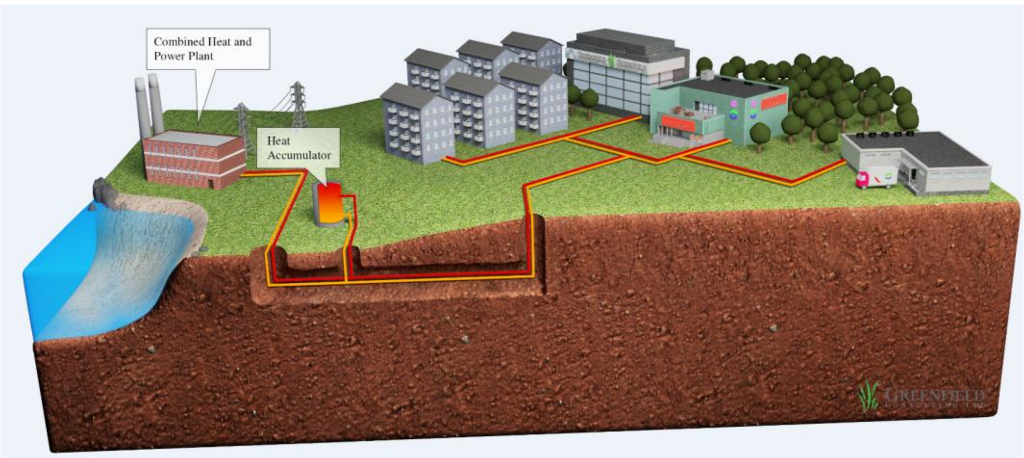

Figure 6: Illustration of a heat network[8]

[7] Codema/BioXL, *A Guide to District Heating in Ireland* (2016)
[8] https://greenfieldgroup.co/community-energy/district-heating-and-chp/ (Accessed October 2016)

At Clonburris SDZ, a heat network (or heat networks) could take various forms. The heat network(s) could be:

- Site-wide, covering all users in the SDZ;
- Partial, covering certain areas and users in the SDZ;
- Integrated with surrounding areas, including the Grange Castle and Clondalkin industrial estates and other existing energy users.

The heat for the network could come from a wide variety of sources, which may include gas boilers or combined heat and power (CHP) plants; biomass boilers or CHP plants; water-source heat pumps using the heat from a river, aquifer, reservoir or sea; waste heat from industry or power stations; or solar thermal collectors. The network can be served by a single heat source, as is typically initially the case, but over time multiple sources of heat can be connected to various points of the network to form a decentralised energy network.

The various technology options for a heat network at Clonburris SDZ, and their relative advantages and disadvantages, are described in Section 6.5.

6.3 Building-level and block-level energy supply

Building-level energy supply options refer to the familiar cases where a heating system (and potentially an electricity generation and/or cooling system) is installed in each individual building, which may contain a single user. This is the most common situation in domestic buildings in Ireland, and covers a wide range of options including oil, solid fuel and gas boilers, electric heating, and solar thermal, which provide heat; air-conditioners, which provide cooling; air-source and ground-source heat pumps, which can supply heating and cooling; and solar photovoltaic (PV) arrays, which provide electricity.

Block-level energy supply options here refer to cases where a heating system (and potentially an electricity generation and/or cooling system) is shared between multiple users in a block of buildings. This may be a block of domestic apartments, but could also be a collection of non-domestic buildings such as in a shopping centre or office block. The technology options for block-level energy provision include those available for individual building-level energy provision as above, but also small CHP units and water-source heat pumps in cases where a system of several hundred kW or more is required.

The various technology options for building-level and block-level energy provision at Clonburris SDZ, and their relative advantages and disadvantages, are described in Section 6.5.

6.4 Building fabric energy efficiency

Building fabric energy efficiency describes the energy required for space heating and cooling in a building, in order to maintain comfortable internal temperatures. These energy requirements are independent of the source of the energy. The building fabric energy efficiency is influenced primarily by factors such as the effectiveness of the building fabric as an insulator (U-values), and the thermal mass of the building. The shape of the building also influences the fabric energy efficiency, as this will affect the area that is externally exposed.

Building regulations (such as Part L 2011, the current national regulation for dwellings) include standards for fabric energy efficiency, specifying the maximum energy demand for heating and cooling in buildings. To make the standards applicable for a range of buildings, levels are set on the basis of energy demand per year per m^2. As such, current and proposed fabric energy efficiency standards can be used to determine the likely demand for space heating and cooling in future developments, such as those proposed for the Clonburris SDZ. Fabric energy efficiency standards typically sit alongside other energy requirements, including maximum primary energy demand, CO_2 emission rates, and a specified portion of the energy demand that must be met by onsite renewables.

To compare the economic and environmental performance of the various energy provision strategies for the Clonburris SDZ, three relevant fabric energy efficiency standards were defined. These are summarised in Figure 7.

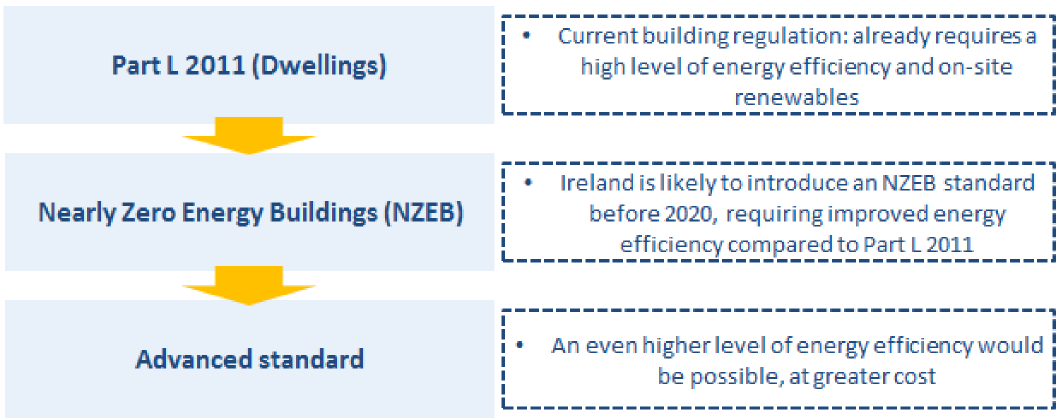

Figure 7: Fabric energy efficiency levels included in the analysis

The current building regulation for Dwellings is the Part L 2011 standard. This already requires a relatively high level of energy efficiency, and on-site renewables (typically solar thermal or solar PV). A new standard, the Nearly Zero Energy Buildings (NZEB) will be introduced before the end of 2020, in line with the EU Energy Performance in Buildings Directive. While the NZEB standard is still under development, previous work on the possible form of the standard for the Department of the Environment, Community and Local Government[9,10] proposes a possible NZEB definition for Ireland, and allows us to estimate the additional cost of meeting the NZEB versus current Part L regulations. It is important to

[9] Department of the Environment, Community and Local Government (DECLG), *Towards Nearly Zero Energy Buildings in Ireland: Planning for 2020 and Beyond* (2012)
[10] AECOM, *Report on the cost-optimal calculations and gap analysis for buildings in Ireland under Directive 2010/31/EU on the energy performance of buildings (recast); Section 1 - Residential buildings* (2013)

note that meeting the NZEB standard will be a requirement for all new buildings by the end of 2020 (if not earlier).

A level of energy efficiency even higher than NZEB would be possible, at greater cost. An example which is partially based on the PassivHaus standard[11], referred to here as "Advanced" is considered. This represents a higher standard that could be taken up voluntarily by future developers, or potentially a future level for the building regulations in Ireland. This level entails a high proportion of renewable energy generation, resulting in a very low level of building energy consumption.

Table 7 sets out the specific energy requirements of these three standards, for typical new dwellings (semi-detached houses and mid-floor apartments).

Table 7: Performance requirements for typical dwellings (new build)

	Part L 2011 (Dwellings)	**NZEB**	**Advanced[12]**
Space heating and hot water demand **($kWh/m^2/yr$)**	24 (Semi-detached); 15 (Mid-floor apartment)	20 (Semi-detached); 9 (Mid-floor apartment)	9 (Semi-detached); 3 (Mid-floor apartment)
Total primary energy demand[13] **($kWh/m^2/yr$)**	54 (Semi-detached); 57 (Mid-floor apartment)	26 (Semi-detached); 52 (Mid-floor apartment)	6 (Semi-detached); 23 (Mid-floor apartment)
CO_2 emissions **($kg/m^2/yr$)**	12	10	<10 (close to zero)
Renewables	Minimum of 10 kWh/m^2 renewable heat or 4 kWh/m^2 renewable electricity or combination	Renewable heat and/or electricity needed to meet the above requirements for energy and CO_2	Renewable heat and/or electricity needed to meet the above requirements for energy and CO_2
Approx. additional fabric cost for typical dwelling **(€)**	-	3,700 (Semi-detached); 1,800 (Apartment)	6,000 (Semi-detached); 4,100 (Apartment)

As can be seen in the first row of the table, the three standards represent an increasing level of fabric energy efficiency for new buildings. The total primary energy and CO_2 emissions specifications assume that a certain level of on-site generation is used to achieve these limits. To achieve the requirements set out in the table, the energy assumed to be provided by on-site generation increases from left to right. Under Part L 2011 and NZEB, it is assumed that either solar thermal hot water generation provides some of the hot water demand, or

[11] See http://www.passivhaus.org.uk/standard.jsp?id=18
[12] "Advanced" standard is defined for our purposes only and is not intended to represent a particular real-world standard
[13] From regulated uses: heating, cooling, ventilation and lighting. Demand met by energy generated on-site is subtracted from the total energy demand.

that electricity generated from on-site PV exceeds the regulated electricity demands and displaces grid electricity in meeting the un-regulated electricity demand. The Advanced requirements assume that both solar thermal hot water and PV are used to meet the energy demand.

The heat and power usage values that inform these standards are based on those set out for different dwelling types and fabric packages in a 2013 report[14] for the SEAI. This report also included assumptions for U-values, fabric costs, and typical dimensions for different types of dwellings. These were used to calculate the costs of the different fabric energy efficiency levels.

Table 8 sets out the assumptions that were used in calculating the primary energy demand and CO_2 emissions rates associated with different levels of energy efficiency and on-site renewables.

Table 8: Key assumptions for energy demand calculations

	Gas	Electricity
Primary energy conversion factor	1.1	1.9
CO_2 intensity (kg/kWh), based on expected 2020 values	0.2	0.46

[14] AECOM, *Report on the cost-optimal calculations and gap analysis for buildings in Ireland under Directive 2010/31/EU on the energy performance of buildings (recast); Section 1 - Residential buildings* (2013)

6.5 Low carbon and renewable technology options

6.5.1 Technology options studied for heat networks

A range of heat supply technologies could be used to supply heat (and potentially electricity) to customers connected to a heat network at Clonburris SDZ. Key options include:

- Gas combined heat and power (CHP)
- Biomass boilers
- Biomass CHP
- Water-source heat pump (WSHP)

These technologies are described below, and are the focus of the economic appraisal of heat network options for Clonburris.

Gas CHP

Gas combined heat and power (CHP) systems generate both electricity and heat. As such, the business case for a gas CHP-based system depends on the ability to sell the generated electricity as well as the generated heat. The heat-to-power ratio of the CHP system can be varied according to the relative size of the heat and electricity demand being served, and value of the sale of each fuel. Typically, CHP systems serving heat networks are heat-led, with heat-to-power ratios on the order of 2:1. A typical gas CHP engine of the type that could be used in the Clonburris SDZ is shown in Figure 9.

In many cases, the electricity generated is exported to the grid, attracting a relatively low value. However, there is also the opportunity to meet the electricity demand of 'on-site' (and, in theory, 'off-site') electricity users through a 'private wire'. In this case, the effective value of the generated electricity is greater, since it offsets the cost of purchasing electricity from the grid, which is significantly higher than the value obtained by exporting to the grid. An important point to note is that, at present, Ireland's Electricity Regulation Act 1999 means that use of a private wire is only allowable if the wire does not at any point pass through land owned by any person or organisation other than the landowner at the origin of the wire, if ESB has refused permission for a connection to the national grid, and if CER has given approval. This means that, even if the relevant agreement were made with ESB and CER, any electricity generated must be used on-site and cannot be delivered to off-site customers. This constrains the use of private wire in Ireland rather strongly. Nonetheless, a private wire arrangement remains possible in theory given the substantial Council ownership of land on the Clonburris SDZ and surrounding area. Furthermore, it is possible that the relevant regulation may have been updated by the time a heat network would be developed at Clonburris, but to our knowledge there are no plans for this.

The main advantages of the gas CHP option are that it is a mature and proven technology, and that it can be cost-effective without any subsidy where there is sufficient heat and electricity demand to serve on-site. The main disadvantage of gas CHP is that it is fossil fuel-based. Currently, gas CHP will lead to limited, but positive, carbon savings, since it operates with relatively high efficiency and the electricity generated offsets more carbon-intensive electricity from the grid. However, as the grid decarbonises, the carbon benefits of gas CHP diminish; once grid electricity falls below a certain carbon intensity, the carbon savings due to gas CHP will become negative i.e. there will be a net increase in carbon emissions. This is illustrated in Figure 8 below (taken from a publication); note that the figure also refers to heat pumps, which are described further below.

The grid carbon intensity in Ireland in 2014 (the latest year for which SEAI data is available) was 457 gCO_2/kWh. At this relatively high grid carbon intensity, it can be seen that gas CHP represents a relatively low carbon option in comparison with both gas boilers and heat pumps. However, as the grid carbon intensity decreases below approximately 350-400 gCO_2/kWh, heat pumps become a lower carbon option. As the grid carbon intensity decreases below approximately 250-300 gCO_2/kWh, gas CHP leads to a net increase in carbon savings as compared with heating with gas boilers and using grid electricity. Given that the plant will operate for at least 20 years, it is important to account for the likely development of the grid carbon intensity over the lifetime of the plant. Ireland's electricity grid is likely to decarbonise significantly over the period to 2030 and beyond, due to increased use of renewable sources (such as wind and bioenergy), meaning that a gas CHP plant installed in 2020 may lead to a net increase in carbon emissions for a substantial proportion of its lifetime.

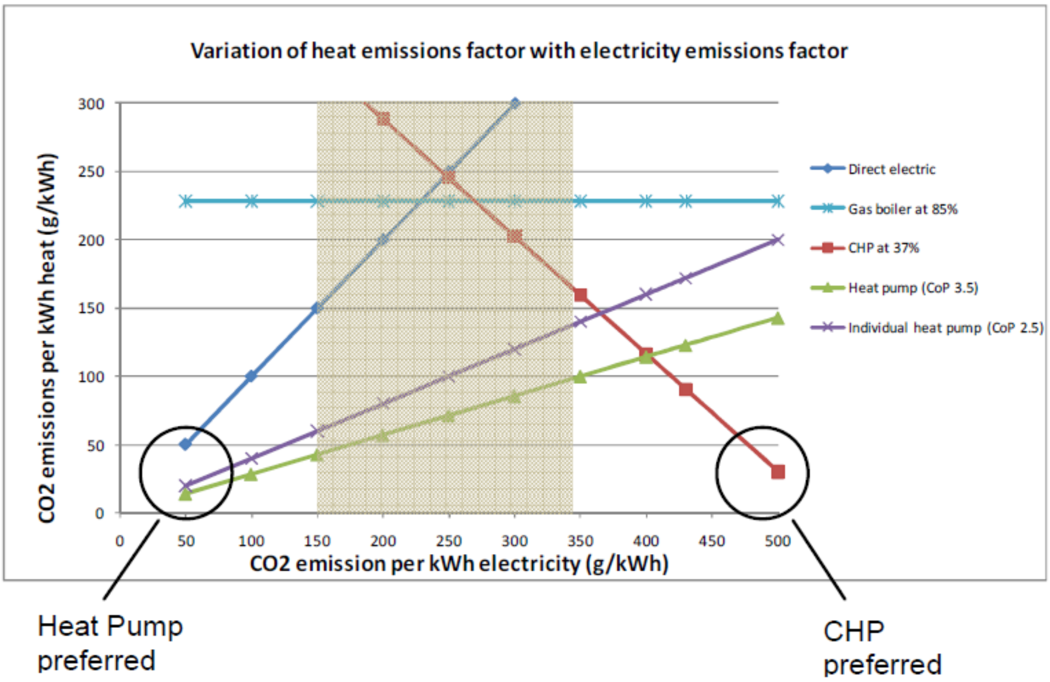

Figure 8: Variation of the CO_2 intensity of heat generated for gas CHP, heat pumps and conventional heating technologies as the grid carbon intensity varies[15].

[15] Figure taken from 'A Heated Debate: Sustainable heat for a low carbon future', Graeme Gidney and Paul Woods, Aecom, 30/10/12

Figure 9: Example Gas CHP engine: General Electric's 1200 kW$_e$ Jenbacher J416 Type-4 engine[16]

Biomass boiler and CHP

Biomass boilers and biomass CHP are an alternative heat supply option. The key advantage of biomass-based systems over gas-based system is the significantly lower carbon intensity of the fuel. It is for this reason that biomass boilers and CHP systems are expected to be eligible for the upcoming Renewable Heat Incentive (RHI) in Ireland, and are currently eligible for the RHI in the UK. Biomass boilers are relatively cost-effective compared with other renewable heating technologies, and likely to be competitive with gas-based systems with an RHI subsidy; biomass CHP is less proven commercially, and likely to be cost-effective only in very large scale application, and with the subsidy. An example of a biomass boiler that could be suitable for a heat network at Clonburris SDZ is shown in Figure 10.

While biomass boilers could be a relatively low-cost low carbon heating option, biomass heating also brings several important drawbacks which must be accounted for in any appraisal of the most suitable heat supply option. The key drawbacks include:

- **Fuel supply logistics and storage**. Assuming delivery of biomass fuel by road, the impact of vehicle movements on local traffic needs to be considered. Furthermore, substantial additional space in the energy centre will be required for a wood fuel store.
- **Impact on air quality** associated with biomass combustion. In particular, biomass combustion releases particulate matter (PM), as well as NOx, whose concentrations should be minimised.
- **Security of fuel supply**. Given the requirement for delivery by road, there is some risk of an interruption to supply associated with access. Furthermore, since biomass is likely to be sourced from a supplier, there is a risk that the supplier will choose to interrupt the contract. As a result, it is recommended to enter into a fuel supply contract with a local supplier.

[16] https://www.clarke-energy.com/gas-engines/type-4-gas-engines/ (Accessed October 2016)

Figure 10: Example Biomass boiler: Binder biomass boiler (from the 500 kW-10 MW range)[17].

Water-source heat pump

Heat pumps extract thermal energy from a renewable source (the source), such as the air, ground or a body of water, transfer the heat to a refrigerant and use an electrically driven compression-expansion cycle to first increase the temperature of the heat and then deliver it to the heated space (the sink).

A water-source heat pump (WSHP) extracts thermal energy from a body of water of some kind. WSHPs may be based on *closed-loop* or *open-loop* systems.

In a closed-loop system, no water is abstracted from the water source. Rather, an enclosed volume of water running through pipework submerged in the water source extracts heat from the water source by conduction, before being transported to the heat pump where the temperature of the water is increased. In an open-loop system, the source water is abstracted through one or more abstraction pipes, before being transported to the heat pump. After the heat pump has removed the heat from the source water, the water is rejected back into the source through one or more rejection pipes.

On the Clonburris site, there is no large body of water at the surface (the canal is highly unlikely to be able to provide the required amount of thermal energy). However, it may be possible to develop an open-loop WSHP system based on abstraction of water from a sub-surface 'aquifer'. In order to establish whether the site could be suitable for such a system, it will be necessary to conduct a hydrogeological study and, likely, to drill a test borehole to measure the 'yield' of water than can be abstracted. A single pair of boreholes (one extraction and one rejection borehole) can deliver between 250 kW and 500 kW of thermal power on a typical suitable site. A schematic diagram of an open-loop borehole system is shown in Figure 11, and an example WSHP is shown in Figure 12.

The key advantage of heat pumps is the potential for very low carbon intensity, if and when the electricity grid is decarbonised. As shown in Figure 8 above, as the grid carbon intensity decreases below approximately 350-400 gCO_2/kWh, heat pumps become a lower carbon option than gas CHP. A range of heat sources can be used with the heat pump, and there is the potential to incorporate waste heat sources from industry, power stations and water

[17] http://www.woodenergy.com/our-products/binder-biomass-boilers-200kw-10mw/ (Accessed October 2016)

treatment works, for example. Furthermore, heat pumps do not present the same air quality, noise and security of fuel supply challenges as biomass.

However, there are a number of drawbacks of WSHP systems. Heat pumps typically have a high capital cost, and they may or may not be cost-effective in the absence of a subsidy (although the economic case for a heat pump is significantly improved where there is a cooling demand). In addition, the electrical power requirement may be large, meaning that grid connection capacity may need to be increased. Further disadvantages are the potentially large space requirement for a borehole array, and potential challenges of environmental permitting for abstraction and rejection of ground-water.

The relative pros and cons of the heat supply options are summarised in Table 9. Typical cost and performance data for each of the technologies are also presented in the table.

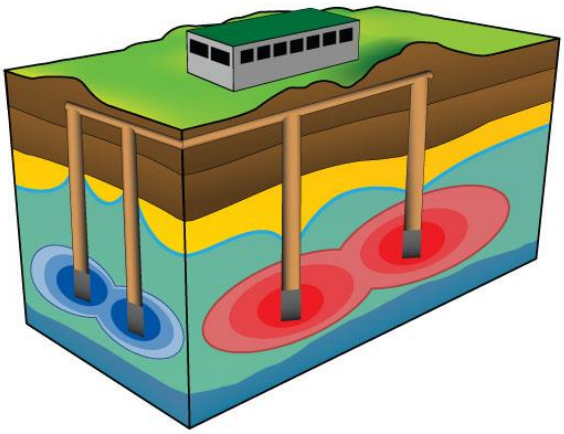

Figure 11: Schematic of an open-loop system involving abstraction and rejection of aquifer water. Image courtesy of G-Core (2016).

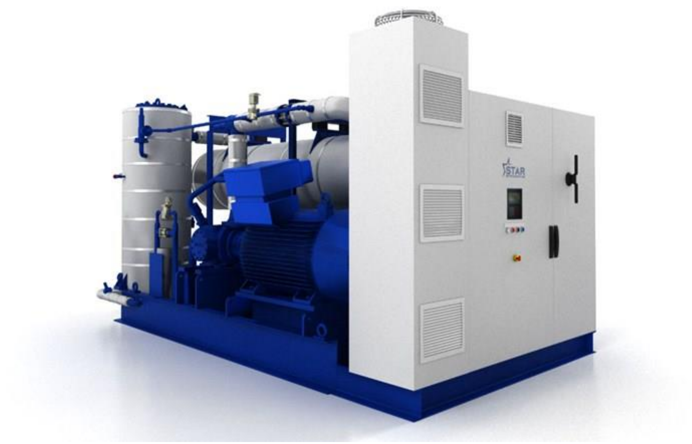

Figure 12: Example WSHP: Star Refrigeration's Neatpump, available from 350 kW_{th} to 6,000 kW_{th} (capacity and dimensions of model shown not known)[18].

[18] http://www.star-ref.co.uk/our-products/neatpump.aspx (Accessed October 2016)

Table 9: Summary of pros, cons, typical cost and performance or heat supply techs

Option	Pros	Cons	Typical cost and performance
Gas CHP	✓ **Mature and proven** technology ✓ Relatively **cost-effective** without subsidy (particularly with private wire electricity supply) ✓ Opportunity to deliver **on-site electricity**	• Fossil fuel-based, so **carbon savings may not be large** (and may be negative in future)	Capital cost: €970/kW$_{th}$ Maintenance cost: €22/kW$_{th}$/yr Total efficiency: 85% Heat to power ratio: 1 to 2 units of heat per unit of electricity
Biomass boiler	✓ Potential to be very **low carbon** ✓ Biomass boiler technology relatively **mature and cost-effective**	• **Regular deliveries and/or large storage required** for biomass • **Environmental issues** (appearance, odours, etc.)	Capital cost: €133/kW$_{th}$ Maintenance cost: €21/kW$_{th}$/yr Thermal efficiency: 85%
Biomass CHP	✓ Potential to be very **low carbon**	• **Regular deliveries and/or large storage required** for biomass • **Environmental issues** (appearance, odours, etc.) • **Biomass CHP remains high cost** and **relatively unproven** technology	Capital cost: €2,000/kW$_{th}$ Ongoing cost: €43/kW$_{th}$/yr Maintenance cost: 80% Heat to power ratio: 2 to 3
WSHP	✓ Potential to be very **low carbon** (if grid decarbonises) ✓ Economies may be improved where there is also a **demand for cooling**[19] ✓ Can **extract heat from various sources including waste heat** ✓ Compatible with low temperature heat networks	• High **capital cost** • Requires substantial **electrical grid capacity** • Water source heat pumps can **require significant land or a large body of water**	Capital cost: €1,500/kW$_{th}$ Maintenance cost: €10/kW$_{th}$/yr Thermal efficiency: 250-500% (depending on source/supply temperature; efficiency of 300% typical for 10/70ºC)

[19] Heating and cooling are complementary processes for heat pumps, as cool water is produced as a 'by-product' of heating using a heat pump, and warm water is produced as a 'by-product' of cooling using a heat pump. In this way, winter heating 'charges' the water body with cool water, which can be used for cooling in the summer.

6.5.2 Technology options studied for building-level and block-level energy supply

The costs, characteristics, advantages and disadvantages of a range of building scale heat and power technology options for the Clonburris SDZ are described in Table 10. A detailed comparison of these building-level options is presented in Section 9.

Table 10: Building scale technology options for the Clonburris SDZ assuming the NZEB standard

Option	Pros	Cons	Typical cost and performance
Individual Gas boiler	• Simple, well-understood and reliable technology • Cost-effective (capex and maintenance)	• Relatively high CO_2 emissions	• Capital cost: €2,500-3,000/dwelling • Thermal efficiency: 90%
Community Gas boiler	• As above • Potential economies of scale compared to individual boilers	• Relatively high CO_2 emissions • Requires more heat distribution pipework than individual boilers	• Capex: €100-150/kW • Thermal efficiency: 90%
Individual Air-source heat pump (ASHP)	• Potential to provide low CO_2 heat (if grid decarbonizes) • Well-suited to new build, energy efficient homes	• Costs remain relatively high, despite mature technology • Performance uncertain, particularly in cold conditions	• Capex: €1,250/kW • Thermal efficiency: 250-300%
Community Biomass boiler	• Potential to provide very low carbon heat • Relatively cost-effective	• Requirement for regular fuel deliveries and storage (large footprint) • Air quality impacts	• Capex: €1,000-1,200/kW • Thermal efficiency: 90%
Community Ground-source heat pump (GSHP)	• Potential to provide low CO_2 heat (if grid decarbonizes) • Higher efficiency than air source systems	• Costs remain high and dependent on ground conditions • Significant area required for installation of boreholes	• Capex: €2,500-3,000/kW • Thermal efficiency: 350-400%
Solar PV	• Simple to install and low maintenance technology • Relatively cost-effective following recent price drops	• More effective in areas of high solar insolation • Times of generation (daytime) often poorly matched to domestic usage	• Capex: €800-900/kWe • Electrical output: 750-800 $kWh/kW_p/yr$
Solar thermal	• Reasonably easy installation and low maintenance	• Modest contribution to overall energy requirements • Requires a hot-water tank • Remains a relatively high cost technology	• Capex: €1,500/kW • Thermal output: 600-700 kWh/kWp/y

7 Energy demand mapping

7.1 Energy demand in Clonburris SDZ

Domestic new build energy demand

The energy demand of new domestic buildings at Clonburris SDZ was discussed in detail in Section 6.4. As described in that section, the energy demand will be dependent upon the building regulation or standard to which the buildings are built. Given that the majority of the development at Clonburris will undertaken later than 2020, it likely that most of the dwellings will be built according to Ireland's Nearly Zero Energy Buildings (NZEB) standard. The 'Advanced' level of energy efficiency, leading to further reductions in energy demand, could be possible in later years, if regulations are further tightened, or in earlier years if the developer (or Council) decided to go beyond regulation to achieve greater environmental benefit, for example. The cost implications of this are assessed in Section 9.

In the energy mapping exercise, to feed into the heat network options appraisal, the study includes sensitivities on the new build domestic heat demand including the three levels of energy efficiency standard. This allows us to determine the impact on the potential new build thermal standards on the heat network viability, and whether the possibility of enhanced efficiency standards constitutes a risk to the economic case for a heat network.

Non-domestic new build energy demand

Non-domestic building energy demand is strongly dependent on building type, and substantially more heterogeneous than domestic building energy demand. For example, supermarkets typically have a higher energy demand per unit of floorspace than office buildings, due to the typical requirement for substantial refrigeration and air-conditioning. Even across buildings of similar use types, variation in energy demand can be large, due to the presence of particular energy-using processes. In the absence of metered energy data, the typical approach to modelling energy demand is the use of published energy 'benchmarks'.

For this work, new non-domestic building energy demand (for which there is of course no metered energy data since the buildings have not been constructed) has been estimated based on CIBSE's "Guide F: Energy Efficiency in Buildings" publication and, given the new build nature, relate to the 'Best practice' case.

Definition of clusters

The emerging preferred scenario for development at Clonburris SDZ, as described in Section 4, is a bi-centric pattern with higher density centres at Fonthill and Kishoge, with Fonthill being of higher density than Kishoge. A lower density residential character is expected outside these centres.

Since there is no building-level plan for the development at SDZ, the most appropriate way of studying the heat demand in spatial terms across the site is to define several sub-areas of the SDZ with distinct heat demand characteristics. These areas are defined as:

- **Fonthill high density cluster**. This is defined as the highest density area of the SDZ at full build-out, approximately 9 hectares in size and incorporating all of the employment and 90% of the retail development at Fonthill, as well as approximately 650 dwellings[20], all high density apartments.

- **Kishoge high density cluster**. This is defined as the second highest density area of the SDZ at full build-out, approximately 9 hectares in size and incorporating all of the employment and 90% of the retail development at Kishoge, as well as approximately 650 dwellings as for the Fonthill cluster, all high density apartments.
- **Fonthill & Kishoge**. This includes both the Fonthill and Kishoge high density clusters, as well as the area between the two clusters. The area between the two high density clusters is assumed to include 2,600 dwellings[21], and no non-domestic floorspace.
- **Whole SDZ**. This includes all development on the site.

Three of these areas (excluding the boundary of the whole SDZ, which is given in Figure 1) are shown in Figure 13 on page 40. Given that there is an ongoing iterative process for the preparation of the SDZ Planning Scheme, **the area boundaries shown in Figure 13 should be considered indicative only.** Based on the information described in the Emerging preferred scenario, the development schedule summarised in Table 11 is assumed, for the purposes of this energy masterplan only.

Table 11: Assumed schedule for development within selected areas under the Emerging preferred scenario

Area	Size (ha)	Domestic	Non-domestic
Fonthill cluster	9	650 units (all apartments)	• 20,000 m^2 of employment • 14,500 m^2 of retail including a 2,500 m^2 supermarket • 2,500 m^2 of community floorspace
Kishoge cluster	9	650 units (all apartments)	• 10,000 m^2 of employment • 2,500 m^2 of retail
Fonthill and Kishoge	70	3,900 units (including 1,300 apartments)	• 30,000 m^2 of employment • 17,000 m^2 of retail • 2,500 m^2 of community floorspace
Whole SDZ	166.8	8,368 units (including 2,500 apartments)	• 30,000 m^2 of employment • 21,455 m^2 of retail • 15,000 m^2 of community floorspace

[20] Based on a peak housing density of approximately 70 dwellings per hectare over 9 hectares.
[21] Based on an average housing density of approximately 50 dwellings per hectare over 52 hectares.

Figure 13: Indicative boundaries of the three areas within the SDZ for which energy demand has been estimated, in addition to the energy demand of the whole SDZ. Top: Fonthill cluster (red) and Kishoge cluster (blue); Bottom: Fonthill and Kishoge (purple).

Based on these assumptions, the heat and electricity demand within each of these areas, and across the whole SDZ has been determined. The results are shown in Figure 14 on page 42. It is noted that the case shown corresponds to the application of the NZEB standard for domestic new build, as the most likely case given that the majority of the development at the SDZ is planned for the 2020s. Under the NZEB standard, the annual heat demand is estimated to be 6.2 GWh for Fonthill, 3.2 GWh for Kishoge and 26.9 GWh for the Fonthill & Kishoge. Across the whole SDZ, the annual heat demand is 54.9 GWh. In the Fonthill cluster the majority of the heat demand is from non-domestic buildings, the Kishoge cluster is made up more evenly of domestic and non-domestic demand, and in the Fonthill and Kishoge and Whole scheme cases the heat demand is dominated by the Domestic sector. The annual electricity demand is found to be 5.2 GWh, 1.6 GWh and 15.0 GWh for the Fonthill, Kishoge and Fonthill & Kishoge areas respectively, and 28.6 GWh across the whole SDZ.

The heat density of the areas defined is presented in Figure 15 on page 42. The heat density ranges from 69 GWh/km^2 for Fonthill, to 35 GWh/km^2 for Kishoge and 38 GWh/km^2 for Fonthill & Kishoge, to 24 GWh/km^2 for the whole SDZ. As discussed in more detail in Section 8, the heat density is a key factor in the viability of a heat network. In Section 8, the viability of a heat network at Clonburris SDZ is assessed in detail; however, it is informative to compare the heat density values derived here with typical 'rules of thumb' used by heat network planners/developers in making a high level appraisal of the viability of a heat network in a certain area. The ‘rule of thumb’ values vary in different sources, but as described in SDCC’s *South Dublin Spatial Energy Demand Analysis*[22], municipalities in Denmark deem an area suitable for a heat network when the heat density is found to be greater than 150 TJ//km^2, which is equivalent to 42 GWh/km^2. By this measure, Fonthill has sufficient heat density to make a heat network viable. The Whole SDZ is not sufficiently heat dense, with only around half the heat density required by the ‘rule of thumb’ threshold. The heat density in the Kishoge, and Fonthill and Kishoge, cases falls just short, but not by a large margin.

The main reasons for the relatively low heat density across the Clonburris SDZ as a whole are the new build nature of the site, for which thermal regulation is likely to be stringent, and the predominance of relatively low density domestic development outside Fonthill. Nonetheless, the hubs, and potentially a larger scheme connecting the hubs, appear to be of interest from the perspective of a heat network. It is also important to note that the ‘rule of thumb’ value for the threshold heat network suitability contains a large number of implicit assumptions on the cost of heating by alternative (non-heat network) means, as well as the location-specific details of fuel costs and access of the network to heat sources. As such, a more detailed and location-specific economic assessment is required to make a more informed statement of the viability of a heat network at Clonburris.

[22] South Dublin County Council/Codema, *South Dublin Spatial Energy Demand Analysis* (2015)

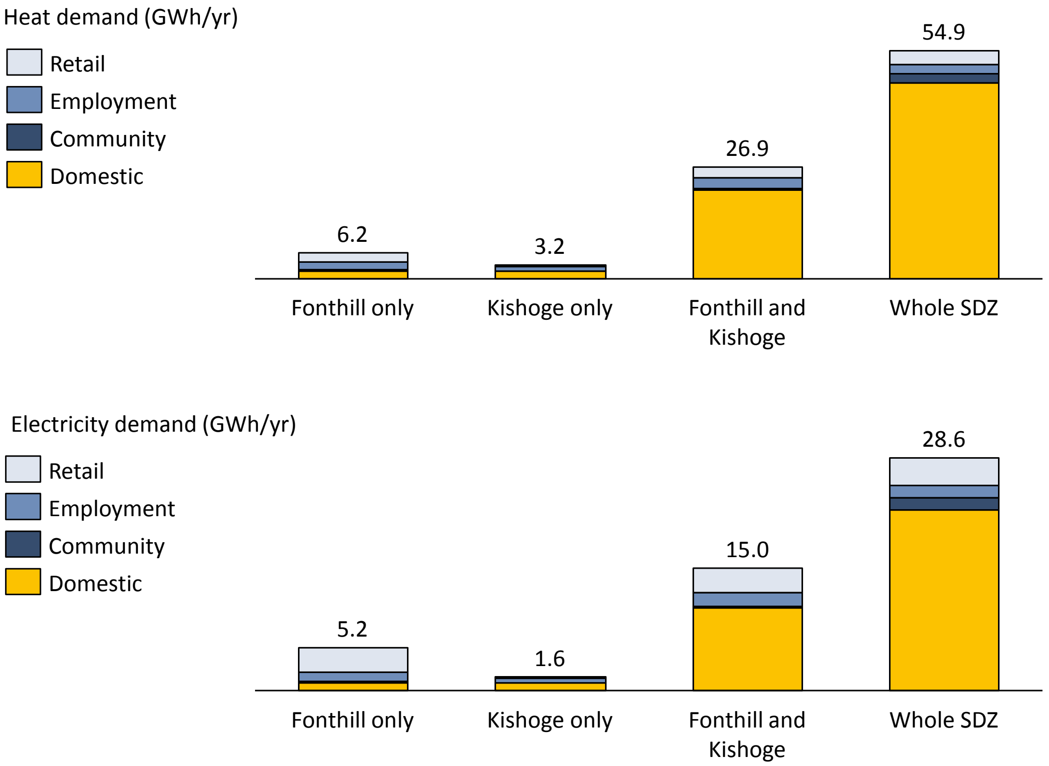

Figure 14: Energy demand of selected areas in Clonburris SDZ in the Emerging preferred scenario assuming the NZEB standard

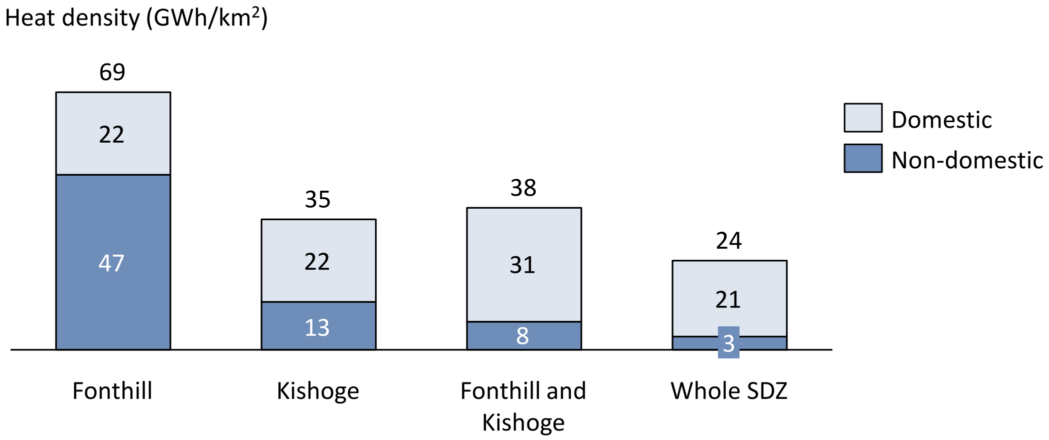

Figure 15: Heat density of selected areas in the Emerging preferred scenario assuming the NZEB standard

7.2 Energy demand in existing surrounding developments

An alternative option for a heat network at Clonburris is one whereby the site is integrated with the surrounding regions. In particular, Clonburris is located in the vicinity of a number of large industrial sites which could – potentially – provide a source of heat for a heat network on the SDZ.

As part of this energy masterplanning work, two high-level options for extension of the network beyond the SDZ which merit further study have been identifed. In order to do this, use has been made of SDCC's *South Dublin Spatial Energy Demand Analysis*[23], an extensive energy demand mapping exercise covering all existing buildings in South Dublin carried out by SDCC and CODEMA in 2015. Figure 4 (in the earlier section 5) presents a map from this report, showing the energy use and location of each commercial and municipal building in South Dublin. The map indicates the presence of a number of large energy users in the vicinity of the SDZ, in particular to the south-west, east and south-east. These users are located in several industrial estates in the near vicinity of the SDZ, including:

- Grange Castle Business Park;
- Clondalkin Industrial Estate;
- Western Industrial Estate.

In this report, an assessment of the viability of a heat network making use of waste heat from these large industrial users is included. More details on these potential configurations are provided in Section 8; here, the heat and electricity demand data taken from the *South Dublin Spatial Energy Demand Analysis* is presented.

[23] South Dublin County Council/Codema, *South Dublin Spatial Energy Demand Analysis* (2015)

7.2.1 Grange Castle Business Park

Grange Castle Business Park hosts a range of large IT, food and pharmaceutical companies. Figure 16 presents the heat and electricity demand of the industrial users in Grange Castle Business Park; the demand of all users in the park, the top 10 users and the top 5 users is shown. It can be seen that the heat demand of the top 5 users in Grange Castle, at 71 GWh, is several times larger than the expected heat demand of the entire Clonburris SDZ at full build-out.

There is an important caveat on the nature of the heat demand for these users; information on the temperature and vector/medium (e.g. water heating or air heating) of these heating processes is not currently available, and it is likely only a fraction of this demand would be suitable as a heat source for a network. However, it is expected that a large proportion of the electricity demand of the IT companies on the site is associated with data centres. Low grade waste heat in the water or air used to cool data centres is potentially recoverable, and could be used as the heat source for a WSHP for a heat network serving the SDZ. This option is studied in Section 8.

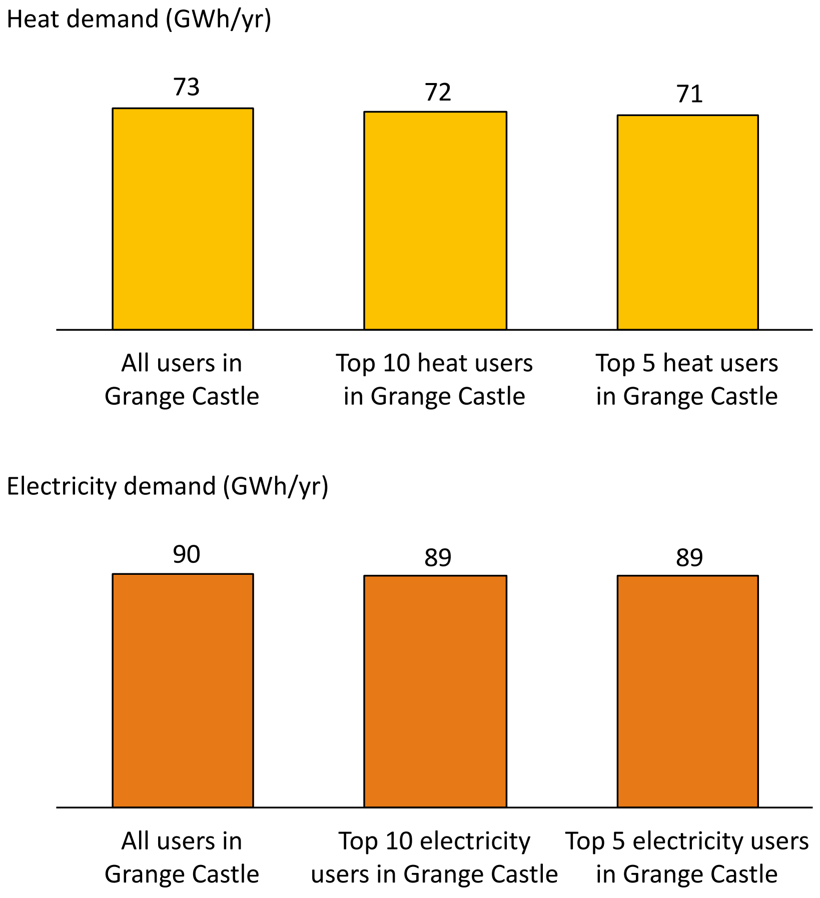

Figure 16: Heat and electricity demand of industrial users in Grange Castle Business Park

7.2.2 Clondalkin and Western Industrial Estates

The Clondalkin and Western Industrial Estates are located to the east and southeast of the Clonburris SDZ, and contain a number of large industrial users which could potentially supply waste heat to a heat network including the Fonthill hub.

Figure 17 shows the heat and electricity demand of the largest industrial users the Clondalkin and Western Industrial Estates; the demand of the top 20 users, the top 10 users and the top 5 users is shown. It can be seen that the heat demand of the top 5 users in the estates have an annual heat demand of 7 GWh, similar to the heat demand of each of the Fonthill and Kishoge hubs.

The nature of the energy-using processes within these industrial organisations is not known, and so similar caveats apply as for the users at Grange Castle, in that only a fraction of the heat demand may be suitable as a source of heat for a heat network on the SDZ. In this case, however, since the total heat and electricity demand in the Clondalkin and Western Industrial Estates is similar to that at the Fonthill hub, and not an order of magnitude larger as in the case of Grange Castle, only a small fraction of the heat required to serve a heat network scheme at Fonthill could be supplied using waste heat from the Clondalkin and Western Industrial Estates.

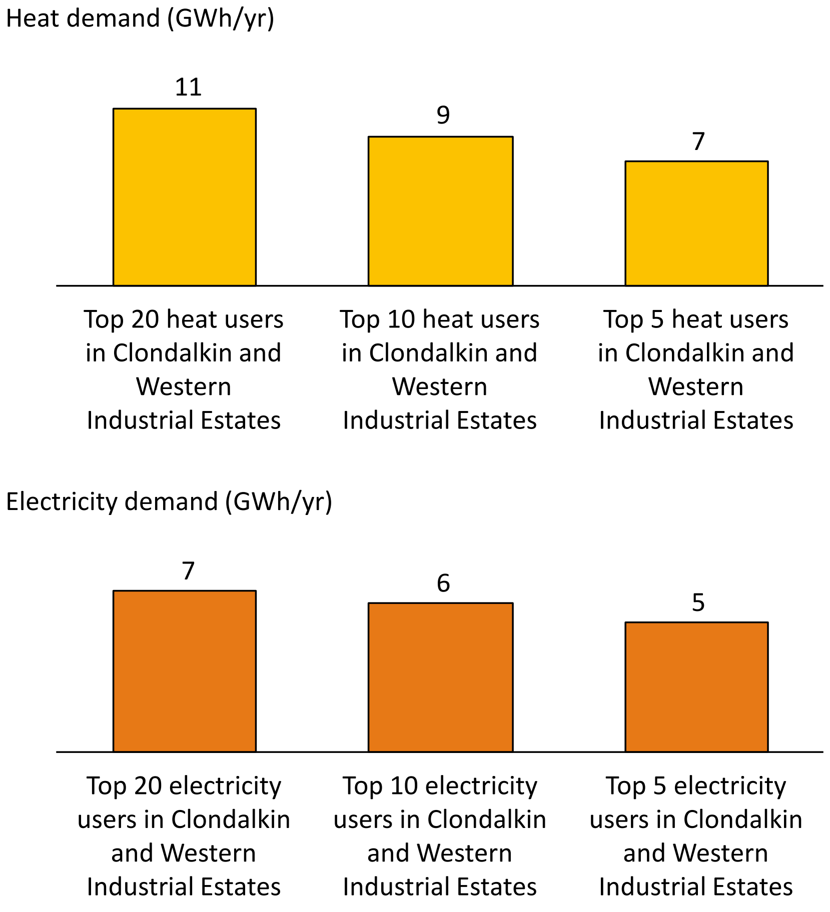

Figure 17: Heat and electricity demand of the largest industrial users in the Clondalkin and Western Industrial Estates

8 Heat network options analysis

8.1 Key characteristics for heat network feasibility

In Section 6.1, the suitability of a site for a heat network was framed in the simple terms of a balance between the benefits of greater diversity and economies of scale brought by the network, and the cost penalty of the infrastructure required for the network. In this picture, the higher the density of the site, and the more diverse the energy demand, the more suitable the site is likely to be for a heat network. However, a wide range of additional factors influence the relative suitability of the heat network, block-level and building-level provision options. The key factors determining the suitability of a site for a heat network are summarised in Table 12.

The high-level assessment of suitability for a heat network at the Clonburris SDZ suggests that many of the characteristics of the SDZ are favourable for a heat network. These include the greenfield and new build nature of the site, which would allow the development to be designed for connection to a heat network, and minimise the cost of civil works to roll out the network infrastructure. Furthermore, there are relatively few constraints on the potential network route, and substantial space for an energy centre (although the value of developable area sacrificed will be an important consideration).

The initial assessment also highlights, however, a number of potential limitations on the suitability. The viability of a heat network at Clonburris is likely to depend on the heat demand density realised, and the identification of anchor heat customers at suitable points in the development phasing. It is expected that clusters around the Fonthill and Kishoge hubs, where the build density will be highest and include a mix of non-domestic and domestic users (including apartment blocks) will be located, may provide the most suitable basis for a heat network. A site-wide network, incorporating the low density domestic semi-detached and detached dwellings, is likely to be less suitable. The potential of connecting one or both of the clusters at the hubs to existing demand in the surrounding regions (such as Grange Castle) could provide the opportunity to extend the network over a larger area.

A key issue will be the phasing of the development, as a heat network typically requires one or more anchor customers to form a ‘critical mass’ to justify the initial outlay of a full or temporary energy centre and a first phase of the network infrastructure; later phases of development may then be built to connect to this nucleus, with the associated network extensions and energy centre upgrades implemented as required.

Nonetheless, the initial high-level assessment suggests that a more detailed economic appraisal should be undertaken, to explore the impact on heat network viability of the drivers described above.

Table 12: Key factors determining suitability of a site for a heat network, applied to Clonburris SDZ

Factor	Characteristics of Clonburris SDZ	High-level suitability rating
High heat demand density	• High heat demand density at the Fonthill hub (69 GWh/km^2 in the Emerging preferred scenario); medium heat demand at Kishoge hub (35 GWh/km^2) • Modest/low heat demand density across the site as a whole (24 GWh/km^2)	**Medium**
Diverse mix of uses	• Development as a whole mainly residential, but non-domestic users at the hubs should provide diversity	**High**
Availability of heat sources	• No existing heat sources on the Clonburris site, but surrounding areas including Grange Castle and other neighbouring developments may provide opportunities	**Medium**
Presence of anchor heat customers	• Development is almost entirely new build, so few existing customers to act as anchor loads • Large potential anchor heat customers in surrounding areas	**Medium**
Significant new development plans	• Development almost entirely new build, offering good opportunity to design for connection to a heat network	**High**
Lack of constraints on route	• Few physical constraints on the site • Potential requirement to cross the canal • Land is greenfield, allowing soft dig to lay pipework	**High**
Significant area for energy centre	• Substantial space on the site, including Council-owned land	**High**
Simple access and wayleave arrangements	• Multiple landowners may be need to be involved, particularly towards the east of the site • Significant Council-owned land could simplify process, particularly towards to west and south of the site	**High**

8.2 Technical design of heat network options

The process for the initial technical design of heat network options can be defined in the following overarching steps:

1. Specify **heat network option**;
2. Determine heat network **demand profile**;
3. Specify network **infrastructure route**;
4. Specify **network parameters**;
5. Specify **plant technical parameters**.

A description of these design steps is given in Table 13.

Table 13: Summary of technical design steps

	Technical design step	Description
1	**Specify heat network option**	• Extent of heat network (e.g. Fonthill only) • User types included (e.g. Non-domestic only) and expected phasing of connection to the heat network • Heat source/supply option (e.g. WSHP)
2	**Determine heat network demand profile**	• For the users included in the network, and according to the phasing plans, determine the annual and peak hourly heat demand across the network • Determine the heat supply temperature required to serve demand
3	**Specify network infrastructure route**	• Specify the location of the energy centre • Taking into account any constraints, specify the route of the heat distribution network and the length of pipework required • Determine the building-level infrastructure required, including heat interface units (HIUs[24]) and heat meters[25] • In the case of CHP supply options, determine the required private wire infrastructure or grid connection route
4	**Specify network parameters**	• Determine the network flow and return temperatures • Specify the network flow speed • Based on the peak heat demand and network temperatures, determine the pipe diameters • Specify the network pressure
5	**Specify plant technical parameters**	• Determine the type and size (e.g. in kW) of heat supply plant required at different stages of phasing • Specify primary plant[26] • Specify peaking/backup plant • Specify thermal storage

[24] Heat interface units transfer heat from the network to a local wet distribution system in each block or building.
[25] Heat meters are required to measure the heat supplied to each block or building, in order to calculate the charge for each customer on the network.
[26] Primary plant is designed to operate with a relatively high 'load factor', i.e. operating typically >4,500 hours per year, as the typically high capital cost of the primary plant require this for the project economics to be viable. Lower cost peaking/backup plant, typically gas boilers, are used to meet peaks in the heat demand, and as backup while the primary plant undergoes maintenance or downtime.

8.3 Heat network options at Clonburris

8.3.1 Heat network options limited to the SDZ

Cluster identification

A key factor which will determine the viability of a heat network at Clonburris SDZ is the heat demand density across the areas covered by the network. According to the energy mapping exercise in Section 7, the area with the highest heat density across the site is that centred on the Fonthill hub (69 GWh/km^2), followed by the Kishoge hub (35 GWh/km^2); the hubs also contain the most diverse mix of users, since they incorporate both domestic and non-domestic development. Further from the hubs, the heat density drops considerably, to 24 GWh/km^2 on average across the whole site, and the user mix becomes much less diverse, as the development is dominated by relatively low density domestic buildings.

As such, the focus areas for a heat network at Clonburris have been identified as the clusters centred on one or both of the Fonthill and Kishoge hubs, where the economic viability of a network is likely to be most favourable. As a next step, it will be considered whether the heat network could expand beyond the immediate vicinity of the hubs, across the area between the two hubs, north and south of the railway line, within the 'Fonthill and Kishoge' boundary described in Section 7.

The boundary of these three areas is shown in Figure 13 on page 40. Given that there is an ongoing iterative process for the preparation of the SDZ Planning Scheme, the scheme boundaries shown in Figure 13 should be considered indicative only.

User types connected to the network

For each of these heat network boundary options, two variations regarding the user types connected to the network are studied: a first variation in which only non-domestic users are connected, and a second variation in which both domestic and non-domestic users (that is, all users) are connected.

The rationale for studying these two variations is that there may be cases where it is economically viable to develop a heat network to serve the non-domestic users, but not the domestic users. Depending upon the density of the domestic development, and the heat demand of each dwelling (which will be determined partly by the level of thermal performance required by the building regulations, which could be very stringent for domestic buildings), the infrastructure cost of connecting a large number of domestic users can be significantly higher, per unit of heat demand, than that of connecting a smaller number of non-domestic users. This is explained further in Section 8.2.

Heat sources and supply options

A range of heat supply options are potentially available to a heat network at Clonburris. As described in Section 6.2, these include gas CHP, biomass boiler or CHP and WSHP. There may also be an opportunity to make use of waste heat from the industrial users at Grange Castle or Clondalkin Industrial Estate, either directly or more likely as a heat source for the WSHP. A range of appropriate supply options for each heat network variant is studied.

The key options for the heat network, as described above, are summarised in Table 14. In the next section, the methodology taken in the high-level technical design of the heat network options, as required to carry out an economic appraisal of the options, is described.

Table 14: Key options studied for a heat network at Clonburris SDZ

Areas of SDZ included	User types included	Extension to surrounding areas	Heat sources/supply options studied
Fonthill only	• Non-domestic only • Domestic and non-domestic	• No extension	• Gas CHP • WSHP • Biomass boiler
		• Extension to Clondalkin/Western industrial estates	• Waste heat from industry + WSHP
Kishoge only	• Non-domestic only • Domestic and non-domestic	• No extension	• Gas CHP • WSHP • Biomass boiler
		• Extension to Grange Castle	• Waste heat from industry + WSHP
Fonthill and Kishoge	• Domestic and non-domestic	• No extension	• Gas CHP • WSHP • Biomass boiler

Network phasing

There is an ongoing iterative process for the preparation of the SDZ Planning Scheme. For the purposes of this energy masterplanning study, the emerging preferred scenario as presented in Table 5 in section 4.2 is assumed. According to this scheme, the development at the Kishoge hub is rolled out over the period 2020-2023, and the development at the Fonthill hub over the period 2026-2029.

In the technical specification of the heat network scheme options above, in line with these phasing assumptions, the Kishoge heat network infrastructure should be constructed in a single phase from 2020 in order that the network route can be laid on greenfield, and that the network is ready for customers to connect as they come on line over the period 2020-2023. Similarly, the Fonthill heat network should be constructed in a single phase from 2026 onwards, for the same reasons.

The Fonthill and Kishoge scheme would then be expected to progress in stages, beginning with the construction of the Kishoge sub-scheme from 2020. Following this, the progression of the network would depend on the phasing of the lower density residential units in the corridor between Kishoge and Fonthill.

Energy centre size

The footprint of the Gas CHP, Biomass or WSHP plant itself is relatively small. For the scale of heat network schemes relevant to Clonburris SDZ, the appropriate capacity of thermal plant is in the range 200–5,000 kW thermal (see later in Table 15). For example, the Gas CHP system in Figure 9, with capacity 1,200 kW electrical (approximately 2,400 kW thermal), has a footprint of around 10 m^2.

However, the overall dimensions of the energy centre are driven by the need to provide additional boiler peaking plant, thermal storage, pumps and other equipment, as well as access. The peak demand for the schemes studied for Clonburris, to which the peaking boiler plant must be designed, is in the range 2–13 MW. A typical footprint for the plant room for a scheme with 2 MW peak demand would be approximately 300 m^2, and for a scheme with 13 MW peak demand would be approximately 500 m^2.

In the case of Biomass boilers, additional floorspace is required for a fuel store. Given the risk of fuel supply interruptions, it is typical to maintain at least one week's worth of fuel supply in a store. Assuming a 1 MW thermal Biomass boiler operating continuously for a week (to represent the case of a peak cold winter week), the daily demand for Biomass fuel is 24 MWh. Assuming a useful thermal content of biomass (after applying an 85% boiler efficiency) of approximately 700 kWh/m^3, one week's fuel supply has a volume of approximately 240 m^3. Finally, assuming a store height of 3m, an additional footprint of approximately 60 m^2 is required for the fuel store. In addition, the fuel store must also be accessed comfortably by a delivery truck.

Network constraints and land ownership

For a predominantly greenfield site such as Clonburris, there is a large degree of flexibility on the network route. Given that there is an ongoing iterative process for the preparation of the SDZ Planning Scheme, there is no proposed layout for the site at the block or building level. As such, there is no basis to propose a detailed route for the network. At this stage, therefore, assumptions are made on the length of network infrastructure required per domestic and non-domestic user based on typical values for sites of density similar to that expected at Clonburris. However, it is possible at this stage to describe the key constraints on the route.

Figure 18 on page 52 shows a constraints map of the Clonburris site, and Figure 19 on page 53 presents a land ownership map. Since the land is largely undeveloped, there is an opportunity to lay the pipework in soft ground, and for the layout to be optimised in terms of pipe length and minimising turns and junctions, which increase the cost of installation. There should also be flexibility in the siting of the energy centre, although the value of the developable land sacrificed would be a consideration. The key constraints for the site will be the railway and the major roads (R113 and R136) passing through the Fonthill and Kishoge hubs, which the network route is very likely to need to cross given the focus of the network options on the hubs. Any extension to the Grange Castle site would require the network to cross the canal, the cost implications of which should be included in a detailed feasibility study.

The land ownership map shows that, on the west side of the site in particular, there is significant opportunity to lay the pipework on land owned by South Dublin County Council, which would greatly simplify the considerations of access and wayleaves. Immediately to the east of the Kishoge hub, however, and surrounding the Fonthill hub, the land ownership is more fragmented and largely private. As such, it is likely that access and wayleaves would need to be arranged with several landowners. It will therefore be critical to engage these stakeholders at the earliest opportunity.

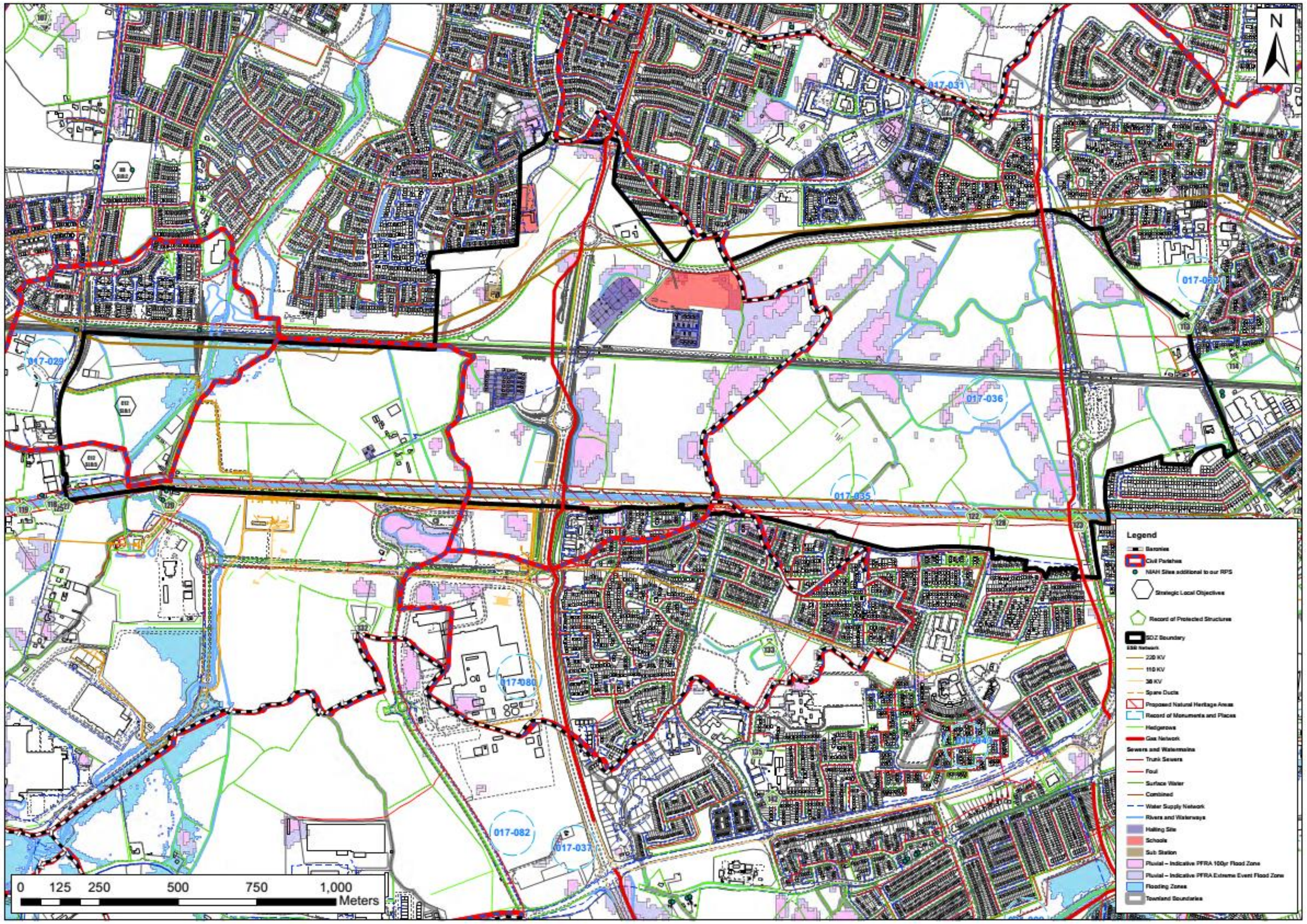

Figure 18: Constraints map for Clonburris SDZ (provided by SDCC)

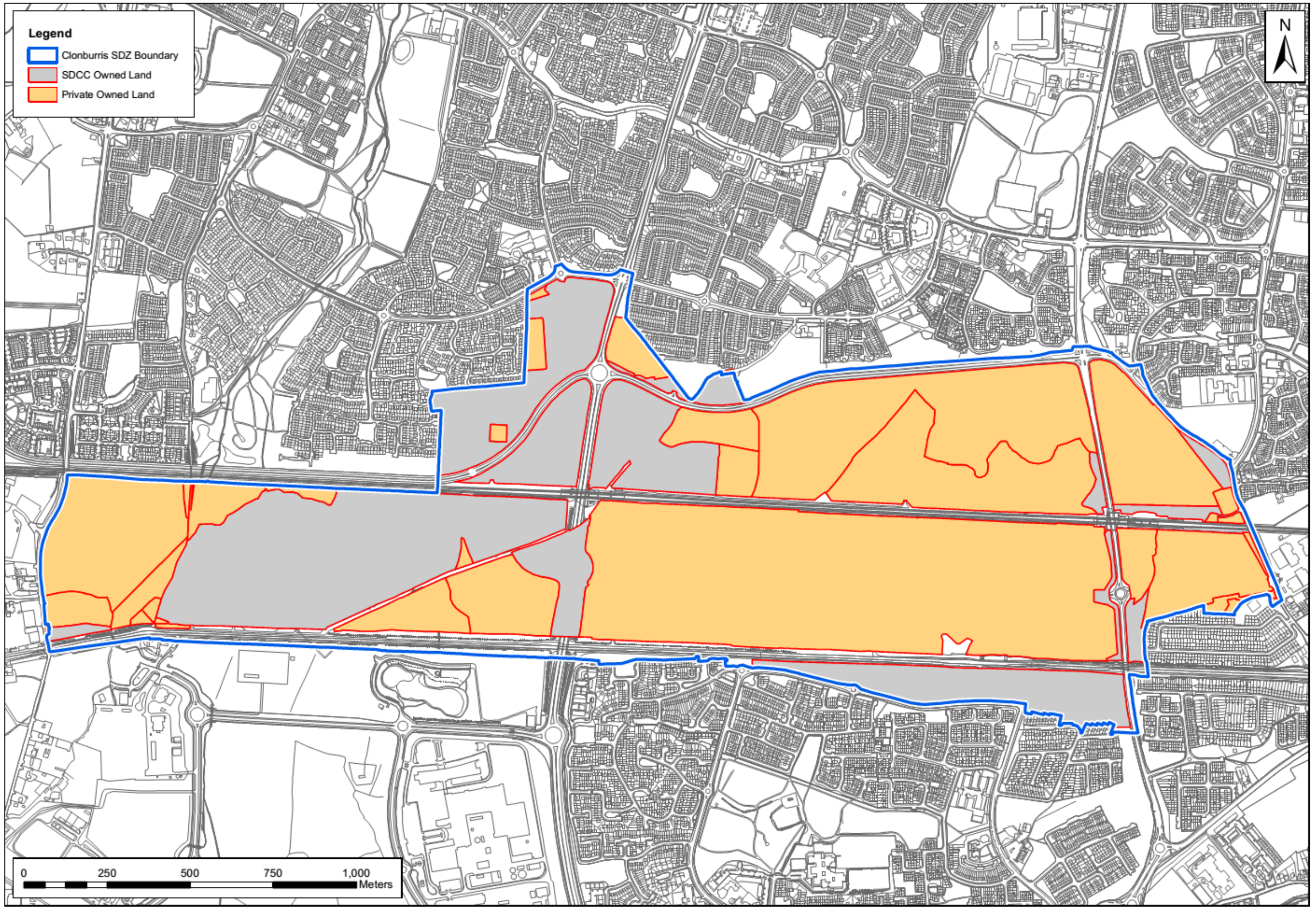

Figure 19: Land ownership map for Clonburris SDZ. Grey regions are SDCC / public-owned; the identity of the other landowners is not indicated.

Energy centre location

Given that the SDZ is still largely undeveloped, there is in theory significant flexibility regarding the location of the energy centre. The basic requirements for the energy centre location are sufficient space for the building footprint (as above, on the order of 300-500 m^2), gas and electricity connections and appropriate access, particularly in the case of Biomass-based heat supply where frequent truck deliveries will be required.

A map of the gas infrastructure in the vicinity of the SDZ is shown in Figure 20; high pressure gas transmission pipes are shown in red. It can be seen that there are major transmission pipes running along both the Fonthill Rd and the Outer Ring Rd, passing north-south through the Fonthill and Kishoge clusters respectively.

An additional consideration is the land ownership; it would be most straightforward to locate the energy centre on SDCC-owned land. In the vicinity of the Fonthill hub, there are several small parcels of land which could be suitable for energy centre; in the vicinity of the Kishoge hub the majority of the land is Council-owned. The energy centre could be a purpose-built, stand-alone building; alternatively, it may be possible to house the energy centre on the site of another suitable building, such as a sports centre, health centre or industrial building.

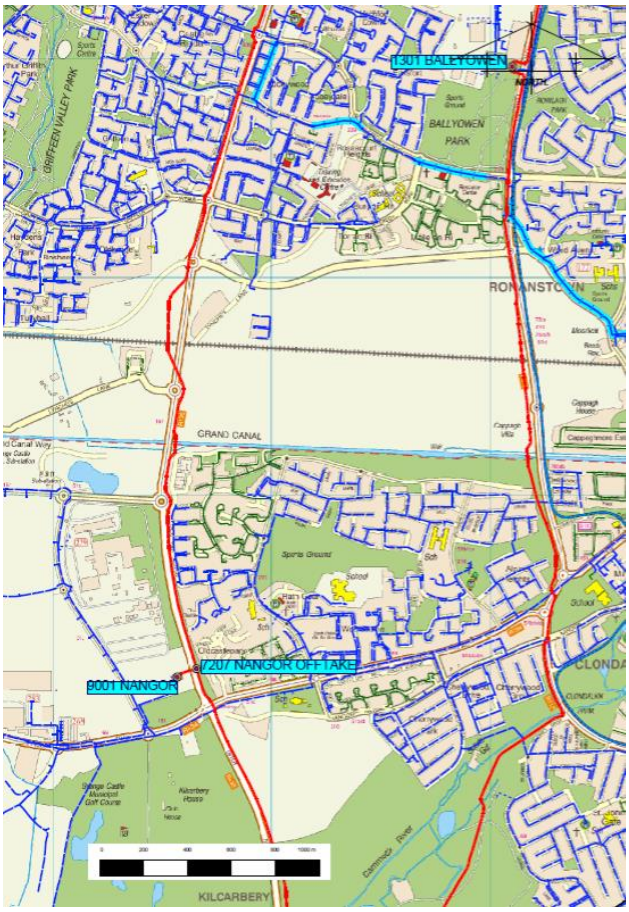

Figure 20: Gas infrastructure map showing high pressure gas transmission pipes (shown in red) in the vicinity of the SDZ [Source: Gas Networks Ireland via SDCC]

Where a variety of location options meeting the above requirements are identified, the main driver for the choice of energy centre location relates to finding a suitable balance between the need to minimise the use of the valuable developable area on the central site (which in this case could mean the energy centre is not located directly at the hubs), the need to minimise concerns relating to the visual and air quality impacts of the energy centre (particularly in the case of a biomass-based system) and the need for the energy centre to be sufficiently close to the heat customers not to lead to a prohibitively high network cost.

A further key consideration will be the specific distribution of the development at each hub. To the extent that the development at the hubs is distributed across the four quadrants defined by the north-south main roads and the railway line, there will be a requirement for the infrastructure to cross the road and/or railway track. If this could be avoided, it would bring a significant cost advantage. This may be possible if the majority of the development occurred in only one, two or three of the quadrants at the hub. This possibility should be considered at such time as the development pattern at the hubs is more clearly defined.

Recognising that there remains significant flexibility on the energy centre location, and uncertainty on the location of buildings with which the energy centre could be co-located, a number of potentially suitable locations are proposed for a stand-alone energy centre for each scheme option, based on the constraints, land ownership and gas infrastructure maps above. These are shown in Figure 21 on page 56, where the red areas would be suitable for a scheme serving Fonthill, and the blue areas would be suitable for a scheme serving Kishoge. A scheme serving Fonthill and Kishoge could include an energy centre at any of these locations. **It is important to note that the area required by the energy centre, at 300-500 m^2, is substantially smaller than the size of the areas highlighted in the figure, and that these are indicative only.**

Each of these options except for F3 has the benefit that the area includes land that is currently owned by SDCC. Each option is located within 500m of the centre of the respective hub, and in some cases much less, reducing the additional network length required. All are located close to an existing gas transmission main, but K1, K2 and F2 have the advantage of being situated on the same side of the relevant north-south main road (R113 or R136) as the gas main. In the case that the network infrastructure can be confined to one, two or three of the quadrants defined at the hub, this could bring a further cost advantage.

Finally, it is noted that in the case that an opportunity to integrate the energy centre into an existing public or industrial building, offering an efficient use of space, the location would clearly be driven by the location of that building.

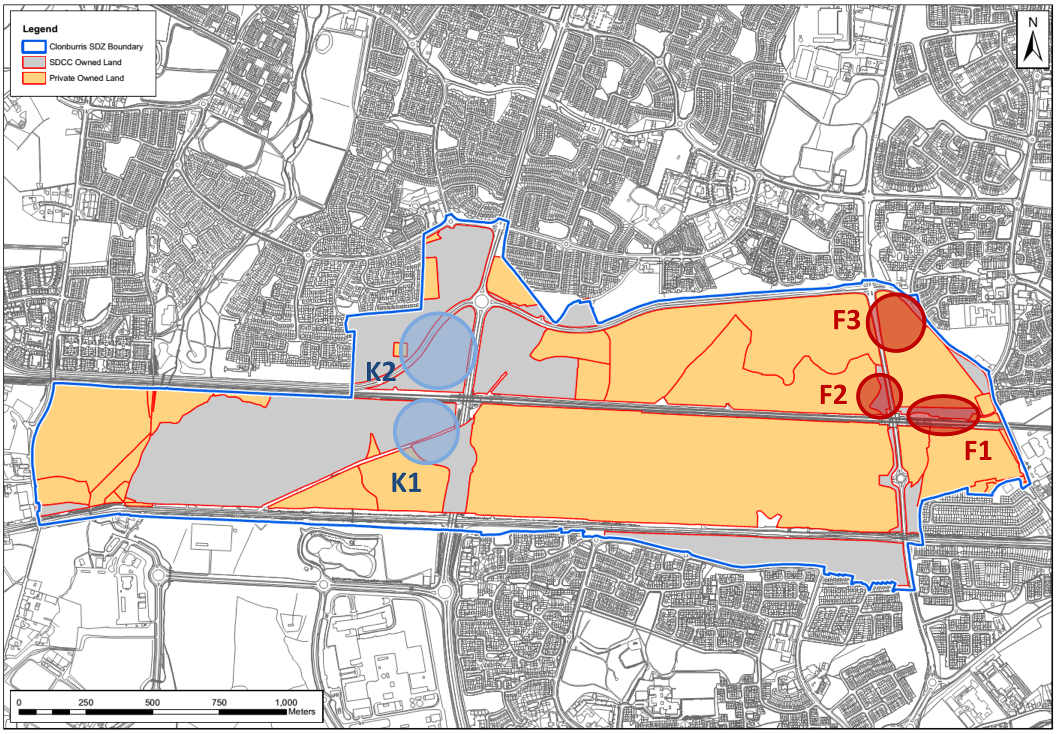

Figure 21: Energy centre location options for heat network schemes based at Fonthill (shown in red) and Kishoge (shown in blue).

Network routes

Given that there is an ongoing iterative process for the preparation of the SDZ Planning Scheme, it is not possible to fully specify the location of buildings which may connect to the heat network and hence the optimal network route. However, it has been possible to develop estimates of the network length based on the emerging preferred scenario for the planning scheme and indicative site layouts.

As shown in Table 11, the Fonthill and Kishoge clusters have been assumed to cover areas of approximately 9 hectares each. According to Figure 13, and consistent with typical block sizes, in a simplified view of the road network as a grid, each cluster can thus be expected to include approximately 3-4 blocks in two perpendicular directions. Figure 22 shows an illustrative heat distribution network that could supply the entire cluster. Note that in this illustration the 'branches' from the distribution pipe to the individual buildings, which would be required in addition, are not shown. The required network length is estimated by this approach as 1.5 km.

As such, a distribution network length of 1.5 km for each of the Fonthill scheme and the Kishoge scheme is assumed. For the Fonthill and Kishoge scheme, the network length is estimated by scaling the length linearly with the area covered by the scheme; since the Fonthill and Kishoge scheme covers 70 hectares, the distribution network length is assumed to be 13.3 km in total.

This length excludes the link from the energy centre to the distribution network. This is clearly dependent on the location of the energy centre. With reference to Figure 21, a length of 300 m for the link is assumed, which is sufficient for the majority of the energy centre location options shown.

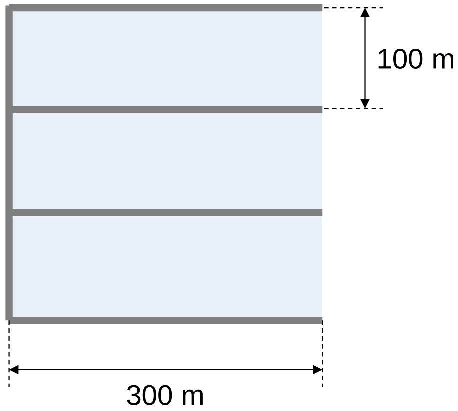

Figure 22: Illustration of a distribution network route (grey lines) supplying a square 9 hectare (300m x 300m) area (blue fill), assuming a block size of 100m. The distribution network length is 1.5 km.

Technical design parameters for heat network options

The key technical design parameters derived, according to the steps described above, for each of the heat network options studied are summarised in Table 15.

Table 15: Selected technical design parameters for heat network options limited to the SDZ in the Emerging preferred scenario

Design parameter (at full build-out)	Fonthill only		Kishoge only		Fonthill and Kishoge	
	Non-domestic only	Domestic and Non-domestic	Non-domestic only	Domestic and Non-domestic	Non-domestic only	Domestic and Non-domestic
Number of domestic connections	0	8	0	8	-	49
Number of non-domestic connections	61	61	40	40	-	101
Annual heat demand (GWh)	4.3	6.2	1.2	3.2	-	26.9
Peak hourly heat demand (MW)	2.9	3.7	0.9	1.8	-	13.3
Length of distribution pipe (km)	1.5	1.5	1.5	1.5	-	13.3
Energy centre link (km)	0.3	0.3	0.3	0.3	-	0.3
Maximum distribution pipe radius (mm)	54	61	30	42	-	280
Network flow/return temperature (ºC)	80/60	80/60	80/60	80/60	-	80/60
Network flow speed (ms^{-1})	2.5	2.5	2.5	2.5	-	2.5
Primary plant size (MW)	0.8	1.3	0.2	0.6	-	4.5
Peaking/backup plant size (MW)	3.5	4.4	1.1	2.2	-	16.0
Thermal storage capacity (MWh)	2.5	3.6	0.7	1.9	-	15.6

8.3.2 Extension to areas surrounding the SDZ

In this section, the option of extending the heat network to incorporate potential sources of waste heat in the existing industrial sites in the surrounding areas is considered. Two potential extensions for this purpose are the Grange Castle Business Park, which could potentially be connected to a heat network at the Kishoge hub, and Clondalkin Industrial Estate, which could potentially be connected to a heat network at the Fonthill hub. The location of these sites are indicated in Figure 23.

Figure 23: Satellite image showing the relative locations of the Clonburris SDZ (red), Grange Castle Business Park (blue) and the Clondalkin and Western industrial estates (orange)

The Grange Castle Business Park hosts a range of large IT, food and pharmaceutical companies. A number of these facilities are known to have large data centres, which will require substantial cooling; where these are water-cooled, this provides a potentially useful source of low grade heat. This is likely to be in the temperature range 10-30ºC. The pharmaceutical and food industries may also have processes leading to the generation of waste heat, potentially in the temperature range 10-50ºC.

In any case, it is very likely that the temperature of the waste heat would need to be raised to meet the required network flow temperature. This could be achieved through use of a WSHP; the higher input temperature would result in an increased operating efficiency of the heat pump compared with supply by an ambient water source, reducing the operating cost (of electricity) for the heat pump.

The viability of these options is assessed in the following section.

8.4 Economic appraisal of heat network options

An economic appraisal of heat network options involves the following key steps:

1. Specify **capital cost** components;
2. Specify **ongoing cost** components;
3. Determine annual **fuel costs**;
4. Determine annual **revenues**;
5. Specify **project finance** parameters;
6. Determine **cashflow** and key performance metrics.

A description of each of these steps is provided in Table 16.

Table 16: Summary of economic appraisal steps

	Economic appraisal step	Description
1	**Specify capital costs**	• Determine capital cost for the scheme, in line with the network phasing, including installation of energy centre, network and building-level components as described in Table 13
2	**Specify ongoing costs**	• Determine ongoing cost of the scheme, including equipment maintenance costs and scheme administration costs
3	**Determine annual fuel costs**	• Determine the expected customer heat demand for each year of the project lifetime • Based on the network technical parameters, determine the expected heat losses across the network • Specify the plant efficiencies • Calculate the annual fuel demand for gas, biomass, electricity and any other fuels • Specify expected fuel prices over the project lifetime • Determine the expected annual fuel costs over the project lifetime
4	**Determine annual revenues**	• Specify the price of heat sold to customers, and any fixed standing charge • Specify the fraction of electricity generated (if relevant i.e. if supply plant is CHP) sold through private wire or exported to the grid, and the electricity sale price in each case • Calculate the expected annual revenues over the project lifetime
5	**Specify project finance parameters**	• Specify debt/equity ratio • Specify fraction of debt derived from public sector, and fraction from private sector, and loan repayment periods • Specify project economic lifetime (typically consider 25 and/or 40 year lifetimes) • Specify equipment lifetime and depreciation periods
6	**Determine cashflow & key performance metrics**	• Determine project cashflow • Calculate project net present value[27] (NPV) and project/equity internal rate of return[28] (IRR)

Economic evaluation metrics

For a heat network to be viable, it must be economically attractive (or at least acceptable) from the perspective of at least three key stakeholder groups:

1. Heat network developer/investor
2. End-user (i.e. heat customer)
3. Building developer

For the **heat network developer/investor**, the project must provide an attractive **rate of return (IRR)** whilst being deliverable in terms of the upfront capital investment.

[27] The net present value (NPV) is the value at the present time of all the cash flows (both positive and negative) of the project.
[28] The internal rate of return (IRR) is the interest rate at which the NPV equals zero. Internal rate of return is used to evaluate the attractiveness of a project or investment.

For the **end-user**, the project must provide an attractive **lifetime cost**, which requires a sufficiently low **price of heat** in order for connection to the heat network to be preferable to alternative heating options.

For the building developer, the key metric is the **upfront cost of the building-level infrastructure** including the heat interface unit, heat meter and the heat distribution system within the building, and how this compares with alternative building services options which would meet the legislated building standards. An important exception to this is where planning permission requires (or strongly favours) connection to the heat network, in which case the developer may have no viable alternative.

These key economic viability metrics are the basis of the options appraisal described in this report.

Note on approach: relation between price of heat, NPV and IRR

The steps described in Table 16 allow an appraisal of the economics of heat network project. This process can be used to compare different heat network options, but also to compare the economics of a heat network with the alternative, block-level and building-level energy provision options.

A typical approach when assessing the economic viability of a heat network is to make an input assumption on the price of heat that could be charged to the customers connected to the network. This price is typically based on the price which would be paid by those customers in the 'counterfactual' case, i.e. if they were not taking heat from a heat network. The price of heat assumed may vary between customers, according to the counterfactual (for example, non-domestic users may experience a lower counterfactual price of heat than domestic users, due to economies of scale; alternatively, domestic customers currently using gas heating are likely to experience a lower counterfactual price of heat than domestic customers using electric heating). The price of heat charged by a heat network should then be no greater than (and ideally less than) the counterfactual price of heat, to incentivise those customers to connect (in the case of existing buildings) and to ensure a fair outcome for the customers (in the case of both existing and new buildings). The NPV and IRR are then outputs of the calculation.

The economic viability of a project is then dependent upon the required rate of return of the investor or investors in the heat network (the various delivery models for a heat network are described in section 13). Private investors in a heat network are likely to require an IRR of at least 10%, and perhaps higher. In contrast, public sector investors (in this case most likely from SDCC) may have a lower cost of capital (for example access to low cost borrowing), and a lower IRR on that portion of the investment may be acceptable.

In this study, as presented in section 9, it is aimed to make a direct comparison of the viability of a heat network against building-level and block-level energy provision options. In this comparison, we fix as an input assumption the minimum required project IRR, and determine as an output the average price of heat that would need to be charged by the heat network developer. This will then allow us to compare the lifetime cost to the end-user of all energy provision options, and thereby determine whether a heat network – or an alternative option – is the most suitable at Clonburris.

Heat network schemes limited to the SDZ: Emerging preferred scenario

Figure 24 shows the results of the economic appraisal of the heat network scheme options limited to the SDZ (i.e. not including any extension to neighbouring sites) and based on gas CHP. It can be seen that the most cost-effective heat network option is that based on both the domestic and non-domestic users at Fonthill only, for which a 10% project IRR can be achieved with an average price of heat of 8.6 c/kWh. A scheme covering the domestic and non-domestic users at Kishoge only is somewhat less cost-effective, requiring an average price of heat of 10.4 c/kWh. A scheme based only on the non-domestic users in the Fonthill scheme requires an average price of heat of 10.1 c/kWh, whereas a non-domestic only scheme at Kishoge is significantly less cost-effective and requires a price of heat of 19.8 c/kWh. This is a result of the low level of non-domestic demand at that hub. The Fonthill and Kishoge scheme, covering both domestic and non-domestic demand, is also substantially less cost-effective than the mixed schemes localised to each of the hubs, and requires an average price of heat 24.2 c/kWh.

The capital cost of the heat network options, as shown in Figure 25, ranges from €1.8 million for the scheme covering non-domestic users only at Kishoge, to €29.3 million for the Fonthill & Kishoge scheme covering all users. It can be seen that the heat network infrastructure accounts for a relatively large proportion of the total investment in each case, but particularly in the less cost-effective options.

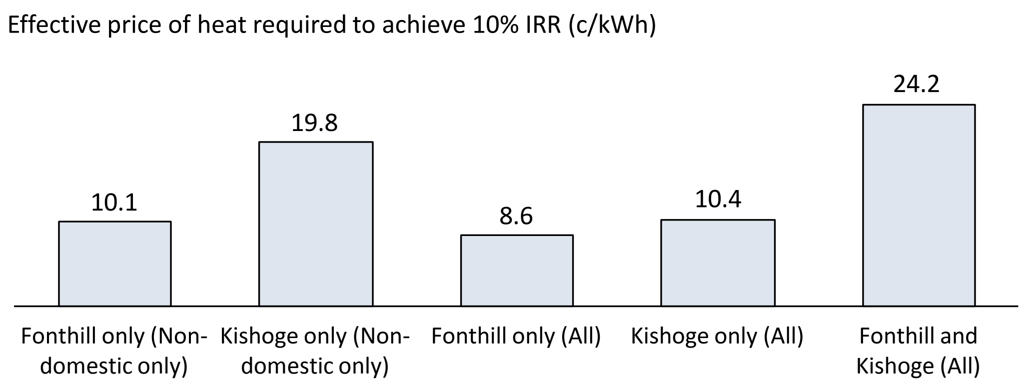

Figure 24: Price of heat required to achieve 10% rate of return, schemes based on Gas CHP (Emerging preferred scenario)

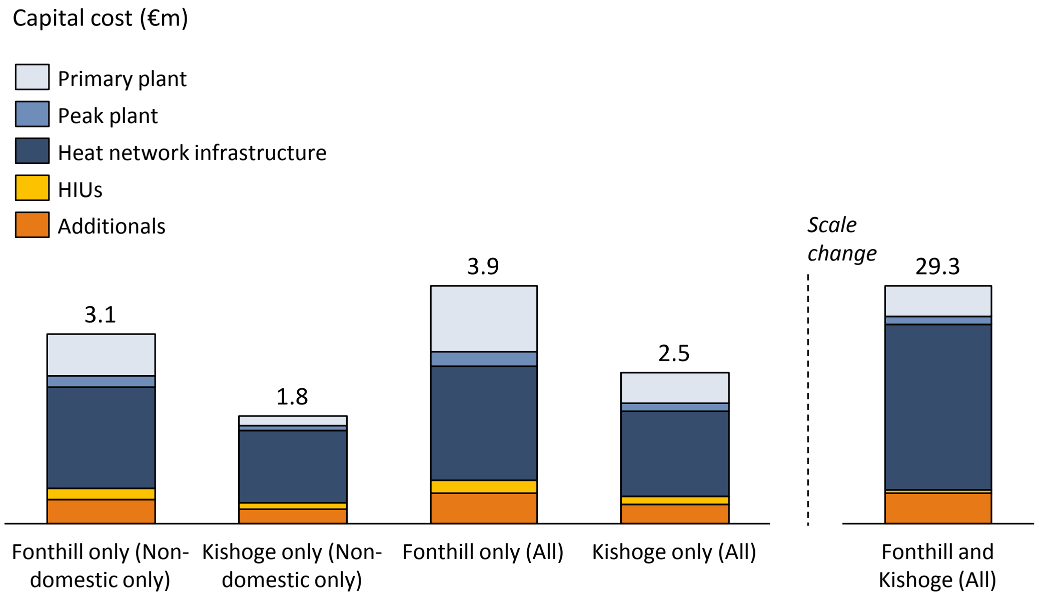

Figure 25: Capital cost, schemes based on Gas CHP in the Emerging preferred scenario

We note that, in Figure 25, the term 'HIUs' refers to heat interface units, which are required to in each building to transfer the heat from the network to the internal building hot water distribution system. The term 'additionals' represents an additional capital cost for contingency, assumed here to be 15% of the total capital cost.

Figure 26 compares the results for the Fonthill only (All) scheme for the Gas CHP, WSHP and Biomass boiler heat supply options. It can be seen that the required average price of heat rises from 8.6 c/kWh for the Gas CHP case to 9.9 c/kWh for the WSHP case with the RHI subsidy[29] and to 13.5 c/kWh in the absence of an RHI. In the Biomass boiler case, the required price of heat is 8.4 c/kWh with the RHI – more cost-effective than the Gas CHP case – and 10.0 c/kWh without the RHI.

[29] In the RHI case, a level of support equal to that currently available in the UK is assumed; an RHI covering WSHPs is expected to be implemented in Ireland in the next 1-2 years, but the support levels are not yet known.

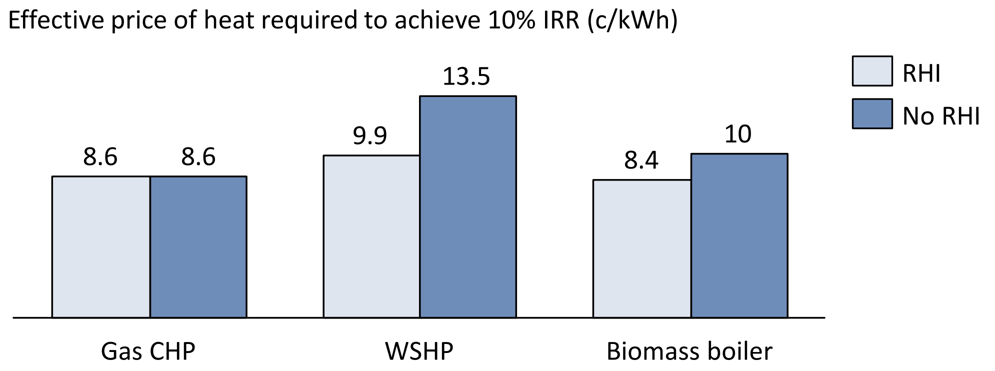

Figure 26: Price of heat required to achieve 10% rate of return for "Fonthill only (All)" scheme, comparison of Gas CHP, WSHP and Biomass boiler heat supply options (Emerging preferred scenario)

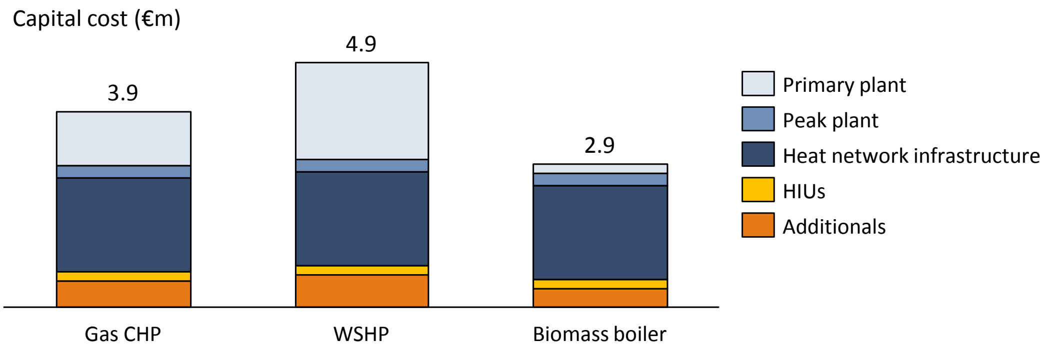

Figure 27: Capital cost for "Fonthill only (All)" scheme, comparison of Gas CHP, WSHP and Biomass boiler heat supply options in the emerging preferred scenario (note: 'Additionals' represents a 15% contingency)

Figure 28, Figure 29 and Figure 30 on page 66 and 67 present the results in a different form. The figures plot the 25-year NPV of the scheme as a function of the price of heat, using two different discount rates of 6% and 10% to represent the typical IRR required by different investor types. As a rule of thumb, a private sector investor is likely to require an expected IRR of at least 10% to invest in a heat network scheme. Public sector bodies, which typically have access to lower cost debt, may be able to provide some or all of the investment, and may apply a lower required IRR in the region of 6% or even lower. As such, the results for the two cases of 6% and 10% are presented. A positive NPV can be viewed as indicating a 'cost-effective' scheme for the relevant discount rate.

Figure 28 presents the results in this form for the Fonthill only (All) scheme, with Gas CHP and WSHP heat supply options. It can be seen that the lower required rate of return of 6% leads to a cost-effective scheme for a price of heat as low as 6.5 c/kWh for the Gas CHP case, and 7.5 c/kWh for the WSHP case (with RHI). Figure 29 presents the corresponding results for the Kishoge only (All) scheme, and shows that the scheme is cost-effective at the lower discount rate of 6% for a price of heat of 8 c/kWh in the Gas CHP case and 8.5 c/kWh in the WSHP case. As shown in Figure 30, even at the lower discount rate of 6%, the Fonthill and Kishoge scheme only becomes cost-effective for a price of heat of 16 c/kWh in the Gas CHP case and just under 18 c/kWh for the WSHP case.

The implications of the price of heat required in these schemes for the overall lifetime cost to the end-user will be studied in Section 9.

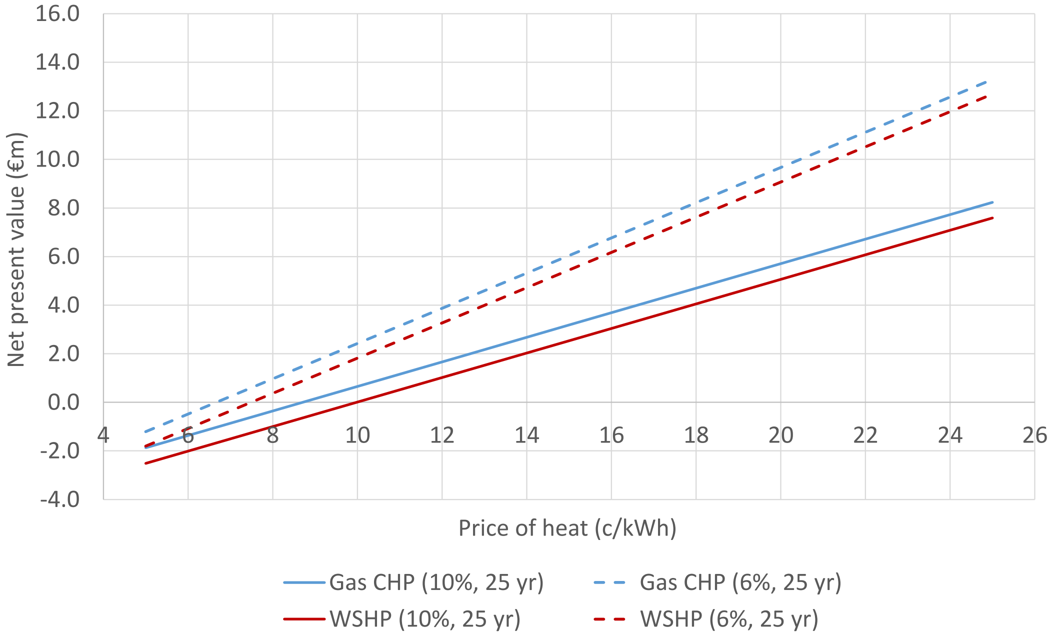

Figure 28: Net present value (25 years) as a function of price of heat for the "Fonthill only (All)" scheme, schemes based on Gas CHP and WSHP with RHI (Emerging preferred scenario)

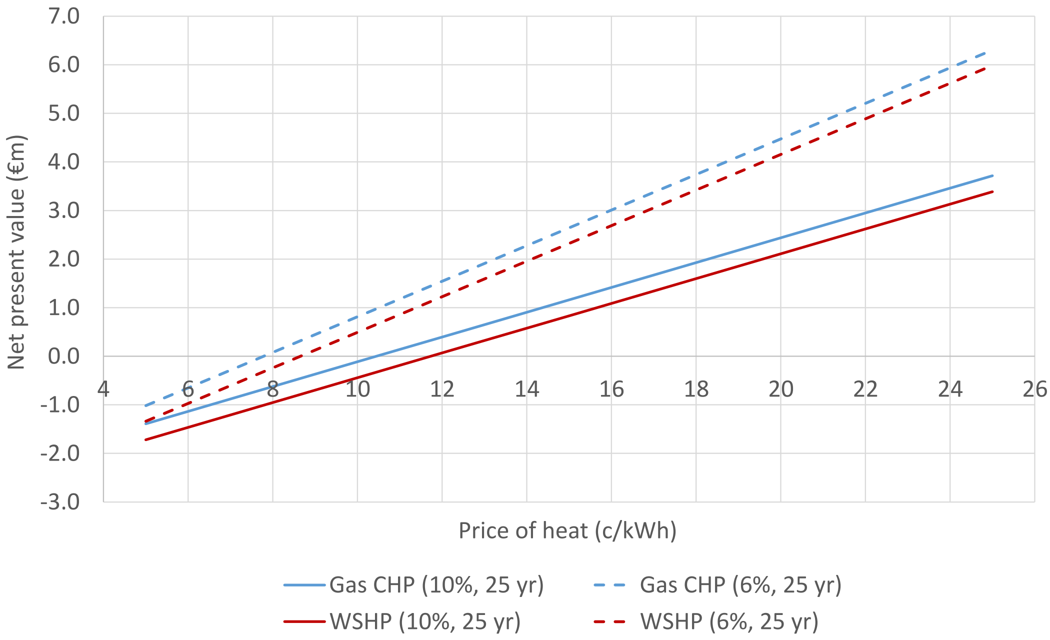

Figure 29: Net present value (25 years) as a function of price of heat for the "Kishoge only (All)" scheme, schemes based on Gas CHP and WSHP with RHI (Emerging preferred scenario)

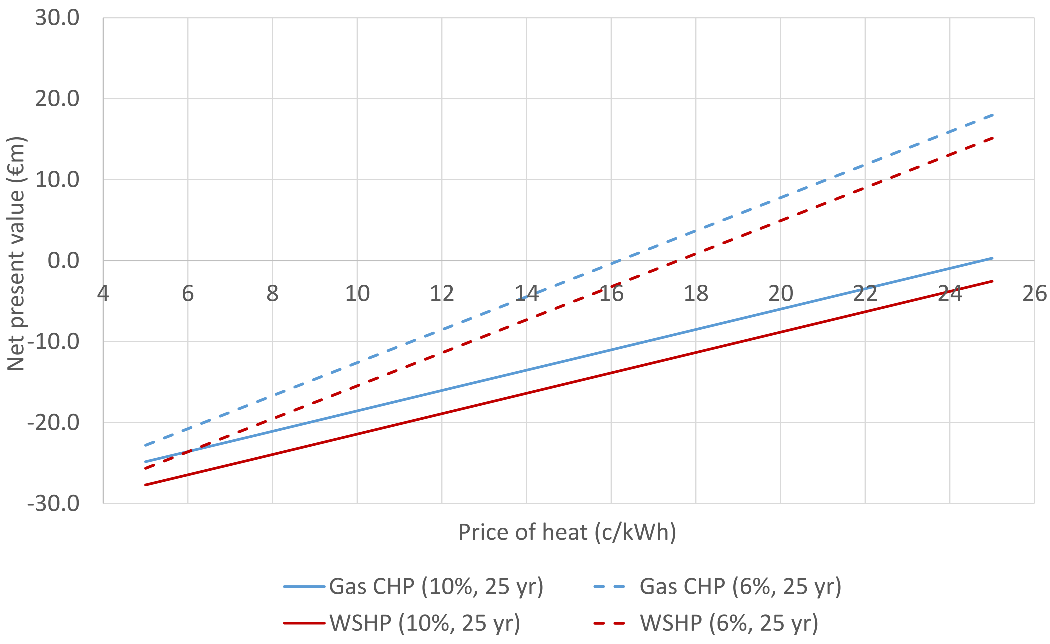

Figure 30: Net present value (25 years) as a function of price of heat for the "Fonthill and Kishoge" scheme, schemes based on Gas CHP and WSHP with RHI (Emerging preferred scenario)

Heat network schemes limited to the SDZ: Enhanced development scenario

As demonstrated above, a very high price of heat is required to achieve a 10% rate of return for the Fonthill and Kishoge scheme and hence make this option commercially attractive to a heat network developer; for a scheme based on Gas CHP, the price of heat required is 24.2 c/kWh. This is unlikely to present a cost-effective option to the end-user, and suggests that it will not be possible to supply heat to the low density residential development outside the hubs.

In order to explore how additional development on the SDZ could impact on this conclusion, there are several sensitivities on an 'Enhanced development' scenario. In this scenario, the impact of an additional quantum of development within the Fonthill and Kishoge scheme boundary on the required price of heat is examined. The impact of increasing the quantum of 'Employment' floorspace is studied, representing a typical non-domestic energy consumption benchmark of 80 kWh/m^2/yr heating demand.

Figure 31 shows that even with an additional quantum of development of 120,000 m^2 of non-domestic floorspace, the required price of heat remains at least 16 c/kWh in the Gas CHP case, significantly larger than the price of heat required for the network options limited to the hubs. This figure represents a high-level estimate, since the activity type of the potential additional development is undefined, but serves to illustrate the low likelihood of a network covering the low density residential areas of the SDZ being viable.

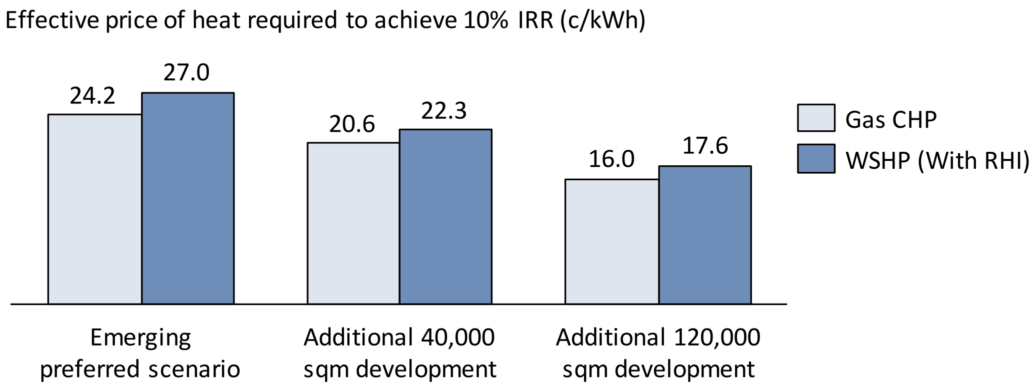

Figure 31: Impact of Enhanced development on the price of heat required to achieve 10% IRR for the Fonthill and Kishoge scheme

Heat network schemes integrated with the surrounding area

Integration of Kishoge scheme with Grange Castle

The electricity demand on the Grange Castle site is very large; the top two electricity users have an annual electricity demand of more than 85 GWh. In comparison, the annual heat demand of the Kishoge cluster is of the order 3 GWh; as such, there is the potential to supply the majority of the heat demand using waste heat from the business park.

Figure 32 on page 70 shows the results of the economic appraisal of the option to integrate the Kishoge scheme with Grange Castle industrial estate, in order to supply the network with waste heat from the industrial site via a WSHP, should this be feasible (as discussed in section 8.3.2). As for the analysis of heat network options limited to the SDZ, the price of heat required to achieve an IRR of 10% is presented. The results shown include an RHI for the WSHP.

The analysis is performed under a number of sensitivities:

- **Transmission pipe length to connect Grange Castle**. A lower bound for the transmission link was estimated above as 1.2 km. Two sensitivities on this, of 1.8 km and 2.4 km are considered.
- **Heat pump efficiency**. The efficiency that could be achieved by a WSHP supplied with waste heat from Grange Castle would depend on the temperature of the waste heat as well as the network flow temperature. Two sensitivities for the heat pump efficiency of 700% and 1000% are studied, an approximate upper bound in the case that the temperature of the waste heat is very close to the required network flow temperature.

It can be seen that the required price of heat is in the range 12.6 c/kWh to 14.0 c/kWh. For comparison, the required price of heat for same scheme supplied by a bespoke energy centre (rather than using waste heat from Grange Castle) is 10.4 c/kWh for a Gas CHP system and 11.9 c/kWh for a WSHP with the RHI. The waste heat option is thus found to be less cost-effective than the on-site energy centre option in all sensitivities.

The capital cost of the waste heat scheme options are shown in Figure 33. It can be seen that the capital cost of the waste heat scheme is significantly higher than for the on-site energy centre case (shown in Figure 25), at €3.8m compared with €2.5m. The additional cost is due to the transmission pipe link.

The large additional network infrastructure cost is not compensated by the increased fuel efficiency of the heat pump based on waste heat. As further evidence of this, the relative insensitivity of the required price of heat to the heat pump efficiency is due to the fact that the cost of the electrical fuel input is a small component of the overall cost, which is dominated by the upfront cost of the infrastructure.

As such, an on-site energy centre appears to be a more cost-effective option to supply heat to the Kishoge scheme than the recovery of waste heat from Grange Castle – this holds true in the case of an on-site WSHP as well as an on-site Gas CHP system. However, it is worth noting that the option of an on-site WSHP is contingent on there being a suitable water source which at Clonburris, given the absence of a major river or water body, is most likely to be subsurface water accessed via a borehole. If further consideration of the hydrogeology of the site concludes that this is not a suitable option (e.g. if the yield is found to be low, or an environmental risk is identified), waste heat from Grange Castle could provide a viable, if less cost-effective, alternative.

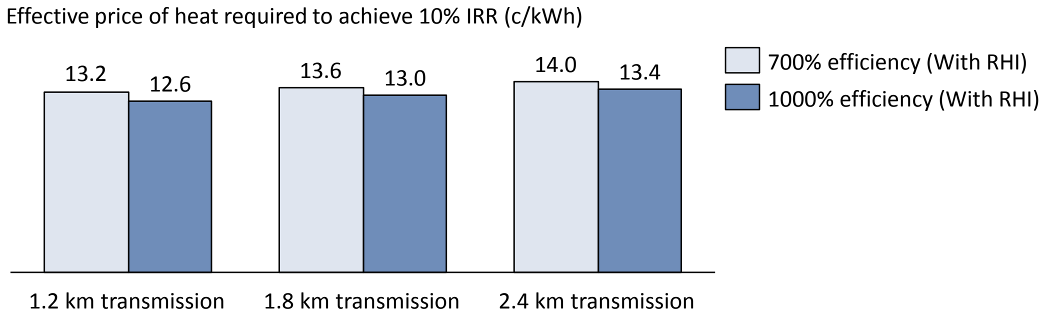

Figure 32: Price of heat required to achieve 10% rate of return for "Kishoge only (All)" scheme supplied by waste heat from Grange Castle with WSHP, for various transmission pipe lengths and WSHP efficiencies (Emerging preferred scenario)

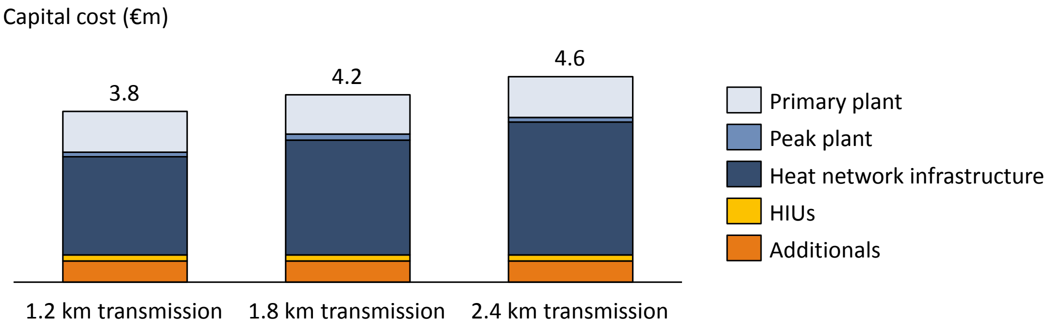

Figure 33: Capital cost for "Kishoge only (All)" scheme supplied by waste heat from Grange Castle with WSHP, for various transmission pipe lengths in the emerging preferred scenario (note: 'Additionals' represents a 15% contingency)

Integration of Fonthill with Clondalkin and Western industrial estates

It may also be possible to capture waste heat from industrial users on the Clondalkin and Western industrial estates to supply a heat network at Fonthill. The nature of the energy-using processes within these industrial organisations is not known, and so similar caveats apply as for the users at Grange Castle, in that only a fraction of the heat demand may be suitable as a source of heat for a heat network on the SDZ. In this case, however, the total heat and electricity demand of the largest 20 users on the Clondalkin and Western Industrial Estates, at 18 GWh (see section 7.2.2) is only several times larger than that of the Fonthill hub at 6 GWh, and not an order of magnitude larger as in the case of Grange Castle. This means that it is likely that only a small fraction of the heat required to serve a heat network scheme at Fonthill could be supplied using waste heat from the Clondalkin and Western Industrial Estates.

A lower bound estimate for the length of transmission pipe required to link the Fonthill scheme with the Clondalkin industrial estate is 1.0 km, but given that waste heat from multiple users would need to be captured, a substantially greater network length than this would be likely.

Given that only a small fraction of the heat demand at Fonthill could be provided by waste heat from the top 20 users at Clondalkin and Western industrial estates, and the fact that would nonetheless require a network length substantially greater than 1.0 km, it is clear that this option is less attractive than the option to supply waste heat from Grange Castle to Kishoge. Given that this, was found to be less cost-effective than an on-site energy centre, it is concluded that the capture of waste heat to supply the Fonthill scheme would not be viable.

9 Building-level and block-level options analysis

This chapter considers the economic and CO_2 impacts associated with the different heating technology options at building and block level. The options are compared in terms of the following metrics:

1. ***Capital cost to developer***
   - This metric will be important to assess the options from the **economic viability perspective**
   - This is the total initial capital outlay that developers incur as a result of implementing the heating technology and any additional fabric efficiency measures, compared against a baseline of current building regulations (Part L 2011).

2. ***Net present value (NPV) per dwelling***
   - This metric is intended to reflect the **lifetime cost-effectiveness** from the **end-user perspective**
   - This is the difference between the present value[30] of cash inflows and the present value of cash outflows over the measure lifetime (here taken as 20 years)
   - As well as capital costs, this takes account of operational costs, such as fuel and maintenance costs, and revenues, such as any sale of electricity back to the grid. Costs of replacing any technology that has a lifetime lower than 20 years (and the residual value after year 20) are also included. Revenues from support tariffs such as Feed-in Tariffs and the Renewable Heat Incentive are not included.

3. ***CO_2 savings***
   - The **environmental benefit** of the options will be assessed based on the CO_2 savings
   - This is the total CO_2 savings achieved over 20 years, compared to a baseline of a dwelling using individual gas boiler heating, with Part L 2011 fabric efficiency).

4. ***Costs of CO_2 savings***
   - The cost of the CO_2 savings can be used to assess the cost of environmental benefit
   - This is the cost of the total CO_2 savings achieved, in terms of the NPV compared to the NPV for a dwelling using individual gas boiler heating, with Part L 2011 fabric efficiency.

These impacts are assessed on the basis of individual dwellings, using characteristics for a mid-floor apartment and for a semi-detached house. Different heating technologies are appropriate for the two dwelling types. While either individual or block-level technologies may be suitable for apartments, only individual technologies are suitable for houses. Biomass boilers are not a realistic option as an individual technology in a semi-urban setting, and are not considered for semi-detached houses. District heating networks are suitable for dense housing areas such as apartments, but are not suitable for houses.

[30] The value of a sum of money in the present, in contrast to the future value of this sum at the time of receipt or expenditure, assuming that it has been invested at compound interest.

Fuel cell micro-CHP is considered for semi-detached houses, but not for apartments, as it is likely that this technology would take up too much space in an apartment. The economic assessment is based on a future scenario in which fuel-cell micro-CHP production has reached high volumes and capex is significantly reduced compared to current prices.

Due to these differences, in the following sections the results are presented separately for the two types of dwellings.

9.1 Impacts of fabric efficiency measures

Capital cost to developer: economic viability perspective

Figure 34 and Figure 35 show the variation in capital costs associated with meeting different fabric energy efficiency standards. The costs shown here assume that individual gas boilers provide the heat supply, and that solar PV is used to meet on-site renewable energy generation requirements.

In the figure legends, several acronyms are used. The term 'PV/SHW' refers to the capital cost of the solar photovoltaic (PV) or solar hot water (SHW) systems as appropriate. In Figure 34 and Figure 35 only PV is present. The term 'CH/DHW tank' refers to the cost of the central heating (CH) system and any domestic hot water (DHW) tank. A CH system is required for all technologies except for air-source heat pumps. A DHW tank is assumed to be present in the case that any heat pump system or SHW is applied.

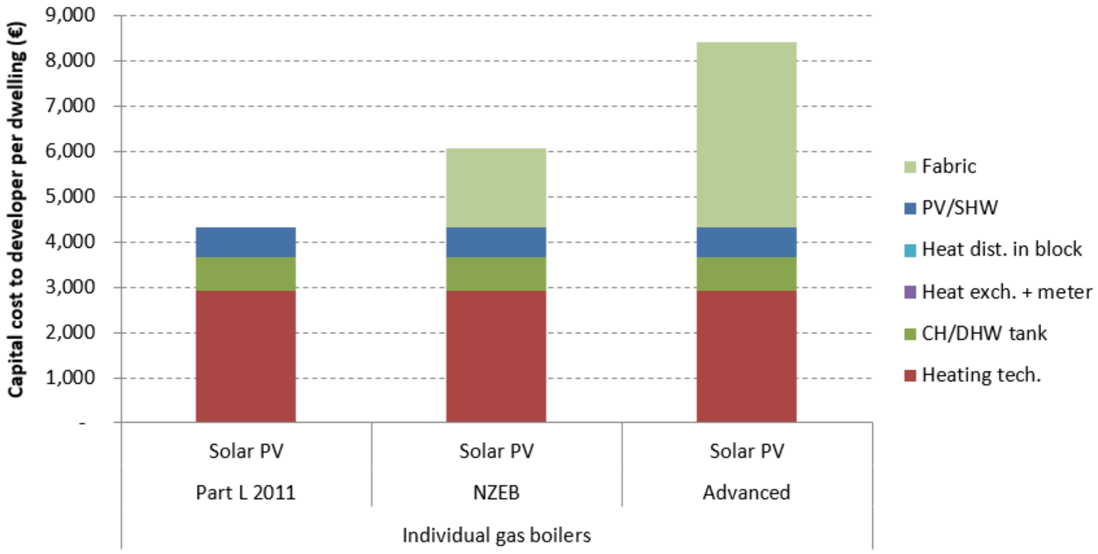

Figure 34: Capital costs to developer: variation with level of fabric energy efficiency for a mid-floor apartment (see footnote for explanation of the terms in the legend[31])

[31] PV: Photovoltaics; SHW: Solar Hot Water; Heat dist. in block: Heat distribution within the block; CH: central heating; DHW: domestic hot water.

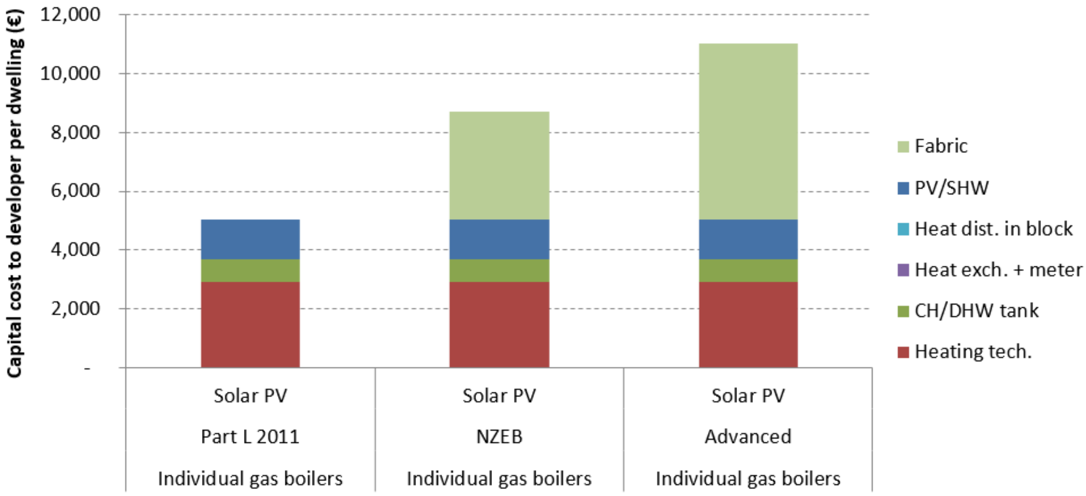

Figure 35: Capital costs to developer: variation with level of fabric energy efficiency for a semi-detached house

For mid-floor apartments, the higher levels of fabric energy efficiency examined here lead to an additional capital cost of around €1,800 for the NZEB standard and €4,100 for the Advanced standard relative to the baseline (Part L 2011, the current regulation). Assuming a total build cost in the region of around €70,000 per apartment, this represents a 3-6% additional upfront cost to the developer, for each apartment with additional fabric energy efficiency measures. For semi-detached houses, the equivalent additional capital cost is higher at €3,700-6,000 per dwelling, due to the additional surface area of this type of dwelling and subsequent greater fabric requirements, compared to mid-floor apartments. It is important to note that meeting the NZEB standard will be a requirement for all new buildings by the end of 2020 (if not earlier), and as such it will not be optional for the building developer to ensure the standard is met.

CO_2 savings and cost of savings: environmental perspective

Figure 36 and Figure 37 show the CO_2 savings that these additional fabric energy efficiency measures could bring over 20 years, relative to the baseline case (Part L 2011 fabric efficiency). Figure 36 shows the CO_2 savings possible for mid-floor apartments, assuming that Solar PV is used to meet renewable energy requirements. Figure 37 shows the CO_2 savings for semi-detached houses for both solar PV and solar thermal cases, with the results indicating that meeting renewables requirements with solar PV could provide higher lifetime CO_2 savings through displacement of grid electricity, compared to doing so using solar thermal (which displaces heat generation).

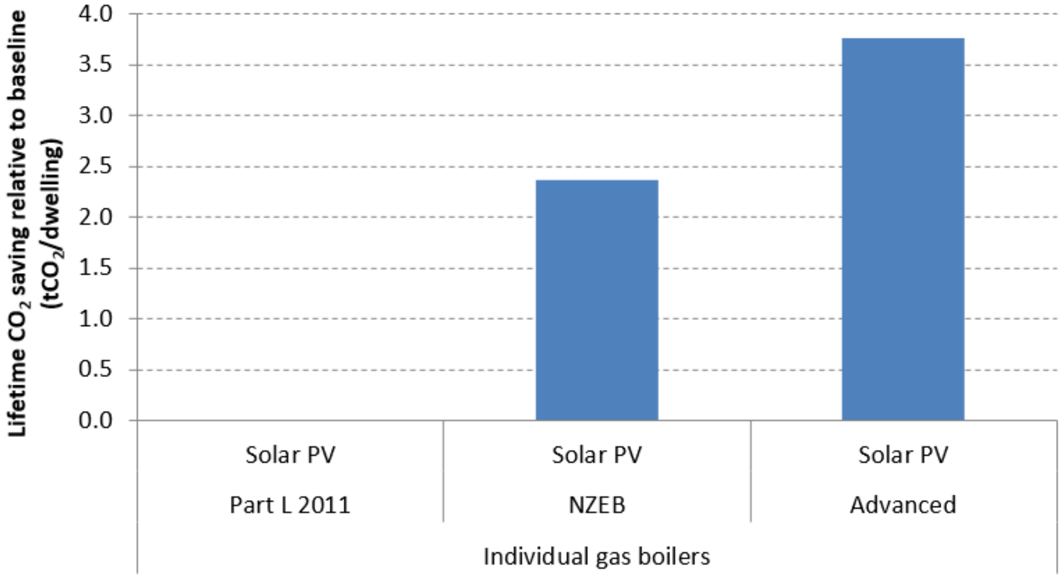

Figure 36: Lifetime CO_2 savings achievable through different levels of fabric efficiency (mid-floor apartment)

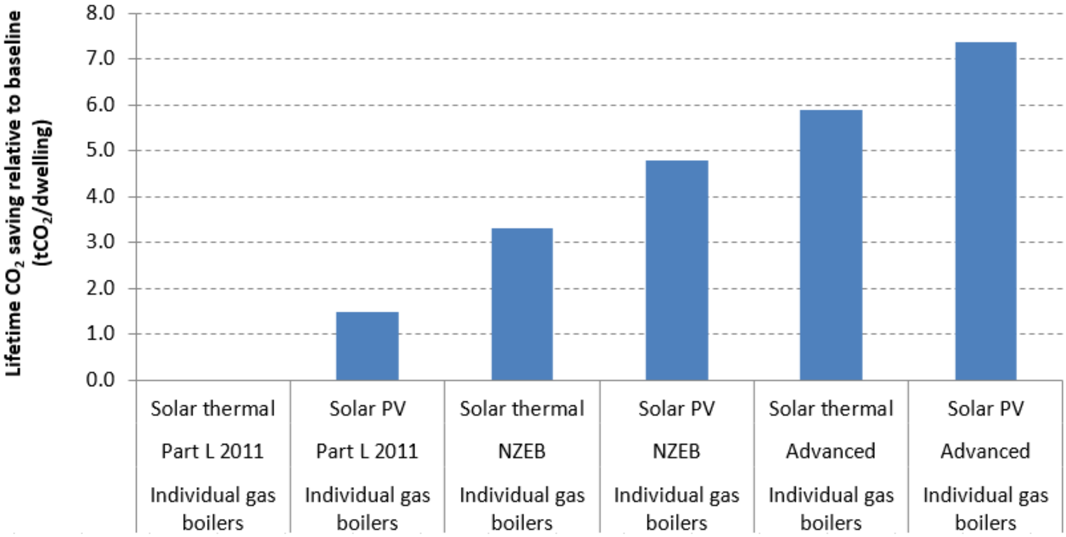

Figure 37: Lifetime CO_2 savings achievable through different levels of fabric efficiency (semi-detached house)

Lifetime CO_2 savings of over 2 tonnes per dwelling (for mid-floor apartments) and at least 3 tonnes per dwelling (for semi-detached houses), are achieved in the NZEB case, relative to the Part L 2011 case, corresponding to around a 20% reduction in regulated emissions. For the Advanced efficiency level, the equivalent lifetime savings are approximately 3.6 tonnes and 6 tonnes per dwelling, for mid-floor apartments and semi-detached houses respectively (for the case where solar PV is used to meet renewables requirements).

Figure 38 and Figure 39 and Figure 40 show the costs of these CO_2 savings, in € (net present value) per tonne of CO_2 saved. This takes account of relative operational costs and revenues, as well as capital costs. Figure 39 shows the cost of the CO_2 savings, using solar PV in the baseline scenario for semi-detached houses, and Figure 40 shows the equivalent costs using solar thermal in the baseline scenario.

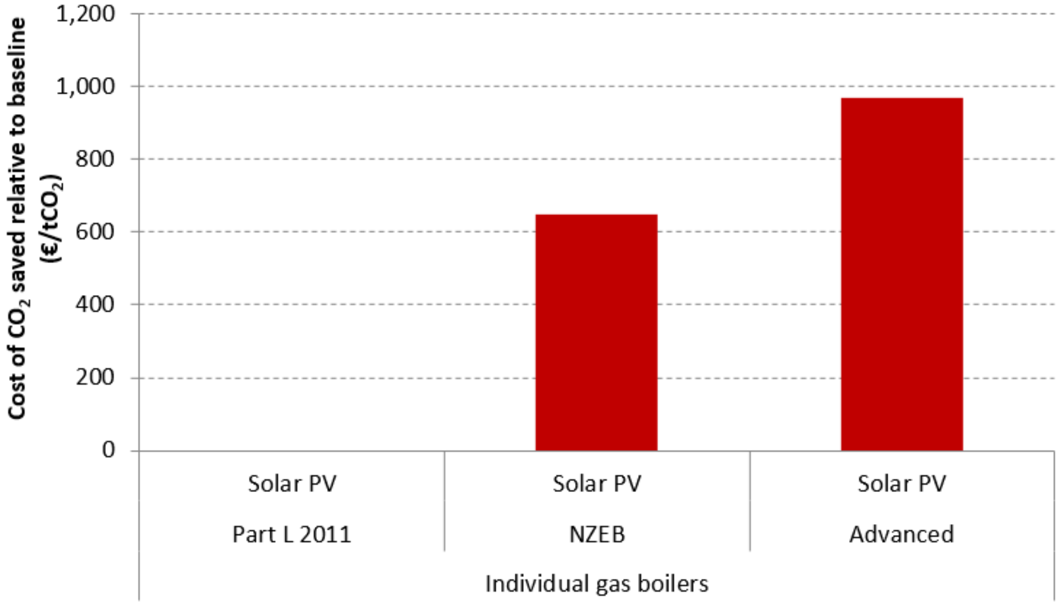

Figure 38: Cost of CO_2 savings achievable through different levels of fabric efficiency (mid-floor apartment with solar PV)

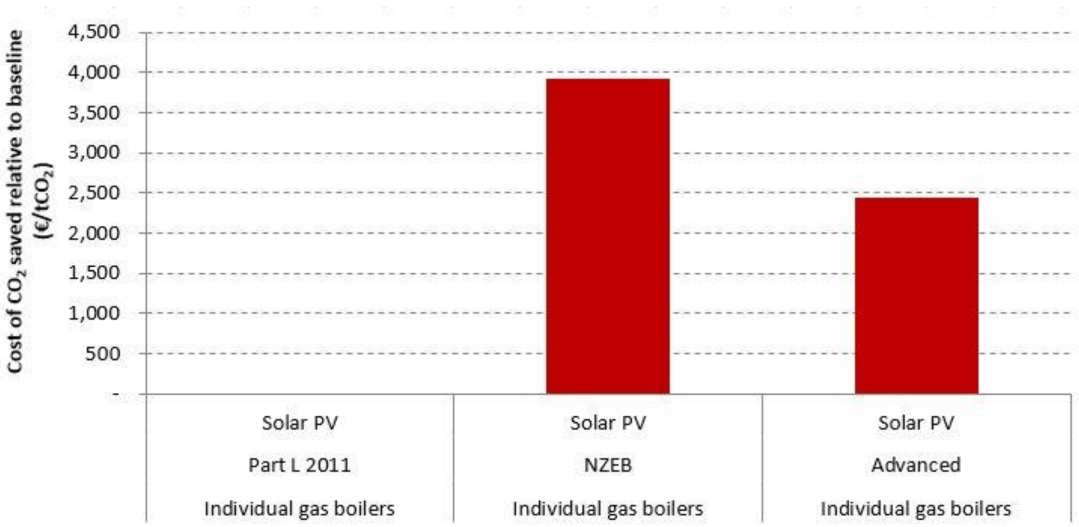

Figure 39: Cost of CO_2 savings achievable through different levels of fabric efficiency (semi-detached house with solar PV)

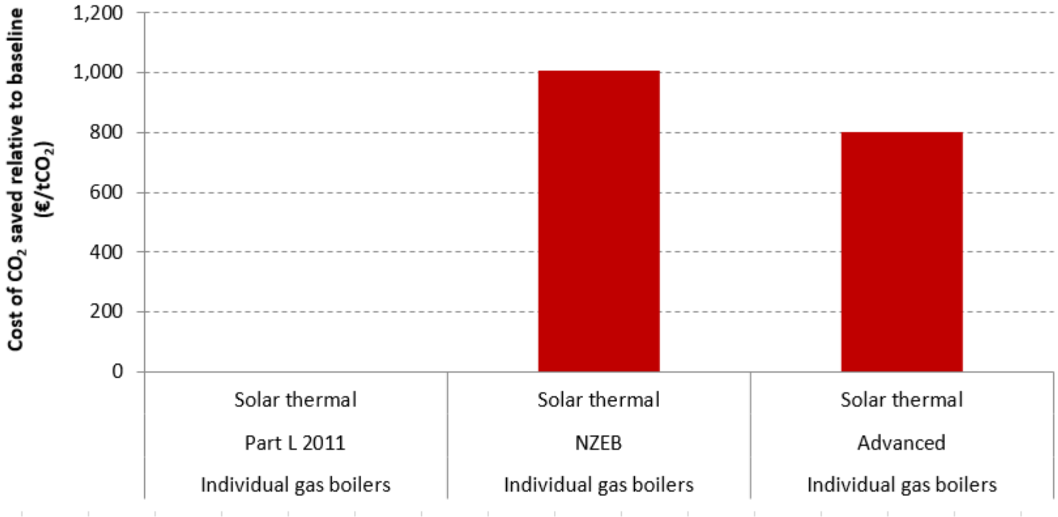

Figure 40: Cost of CO_2 savings achievable through different levels of fabric efficiency (semi-detached house with solar thermal)

The cost of CO_2 savings from improved fabric efficiency is high, at €650 / €4,000 per tonne for the case of NZEB and €970 / €2,500 per tonne for the Advanced efficiency level (values for mid-floor apartments and semi-detached houses respectively, assuming that solar PV is used). This reflects the fact that Part L 2011 is already a relatively stringent level of efficiency, and further efficiency improvements can largely only be achieved through costly measures such as highly efficient glazing and mechanical ventilation heat recovery.

9.2 Impacts of alternative heating technologies

Alternative heating technologies presented

Section 6.5.2 outlined a range of heating technology options available for new buildings at Clonburris SDZ. Here, an economic appraisal of the different options is undertaken. Table 17 summarises the heating system options included in this section.

A different set of heating system options for apartments and for semi-detached is included, as some of the technologies are unsuitable for one of the two building types. For apartments, the available options include individual and community heating systems, as well as connection to a heat network. However, individual GSHP are not suitable for most apartments given the requirement for a large external area for the ground loop. In addition, a micro CHP system is unlikely to be suitable for an apartment, given the large internal space requirement.

For semi-detached homes, all the individual heating systems are applicable. Community heating, as defined here (i.e. a single heating system serving a block of apartments) is not available. The heat network option is also available for semi-detached homes.

Heat network options presented

The economic analysis of heat network options in section 8 demonstrated that the most economically viable scheme – that is, the one allowing the lowest price of heat to customers which remaining attractive to the heat network developer – was the Fonthill scheme, centred on the Fonthill hub. In this case, at 10% IRR could be achieved by a heat network developer with a price of heat of 8.6 c/kWh for the Gas CHP-based scheme, of 13.5 c/kWh for the WSHP-based scheme without RHI and of 9.9 c/kWh for the WSHP-based scheme with RHI.

The Kishoge scheme was found to require only a slightly higher price of heat to become economic under a 10% required IRR.

However, it is important to note that our analysis of the Fonthill scheme assumed only the connection of the high density apartments at the hub, and not the lower density semi-detached and detached housing. The scheme including the lower density housing away from the Fonthill and Kishoge hubs, the Fonthill and Kishoge scheme, was found to require a very high price of heat of 24 c/kWh for the Gas CHP case. For a WSHP without RHI, the required price of heat is 30 c/kWh; with RHI, the required price of heat is 26 c/kWh.

As such, **in the comparison of different heating options for apartments, the Fonthill scheme based on Gas CHP and WSHP is included; for the semi-detached case, the Fonthill and Kishoge scheme based on WSHP is included.**

Table 17: Heating technology options presented in economic appraisal

Building type	Heating system type	Heating system option
Apartment	Individual	Individual gas boiler
		Individual ASHP
	Community	Community gas boiler
		Community GSHP
		Community biomass boiler
	Heat network	Fonthill scheme, based on Gas CHP (8.6 c/kWh)
		Fonthill scheme, based on WSHP (13.5 c/kWh without RHI, 9.9 c/kWh with RHI)
Semi-detached	Individual	Individual gas boiler
		Individual ASHP
		Individual GSHP
		Individual micro CHP
	Heat network	Fonthill and Kishoge scheme, based on WSHP (30 c/kWh without RHI, 26 c/kWh with RHI)

Capital cost to developer: economic viability perspective

Figure 41 and Figure 42 show the variation in capital costs to the developer with different heating technologies, for a fixed level of fabric energy efficiency (shown here for NZEB standard, which is likely to be implemented by 2021 and hence the most likely to apply in the early stages of development at Clonburris). Figure 41 shows the results for mid-floor apartments, and Figure 42 shows the results for semi-detached houses.

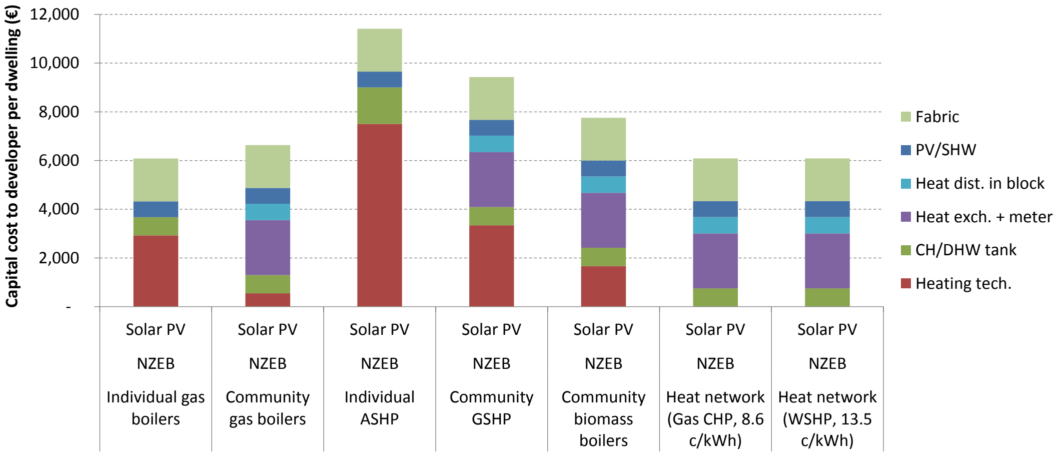

Figure 41: Capital cost to developer: variation with different heating systems (mid-floor apartment)[32]

As shown in Figure 41, for mid-floor apartments all individual and community heating system options lead to some increase in the upfront cost to the developer, relative to the individual gas boiler baseline. The additional cost is in the range €0.5-5.5k, representing an increase in the total build cost of up to ≈9%.

The additional upfront cost to the (building) developer is lowest for community gas boilers. Community heating systems bring the benefit of diversity and economies of scale, allowing the cost of the heating plant to be reduced; however, additional costs are incurred for a block heat distribution system and heat exchangers. The biomass and heat pump heating options are more costly, due to the higher upfront cost of the heating plant; this is especially pronounced for the individual heat pump option.

Under the heat network options, on the other hand, the upfront cost to the developer is approximately the same as with the individual gas boiler baseline, as the avoided cost of the gas boiler is approximately the same as the additional cost incurred for the heat exchanger, heat meter and heat distribution within the block of apartments.

[32] PV/SHW: Photovoltaics or Solar Thermal Hot Water; Heat dist. in block: Heat distribution within the block; CH/DHW tank: hot water storage tank.

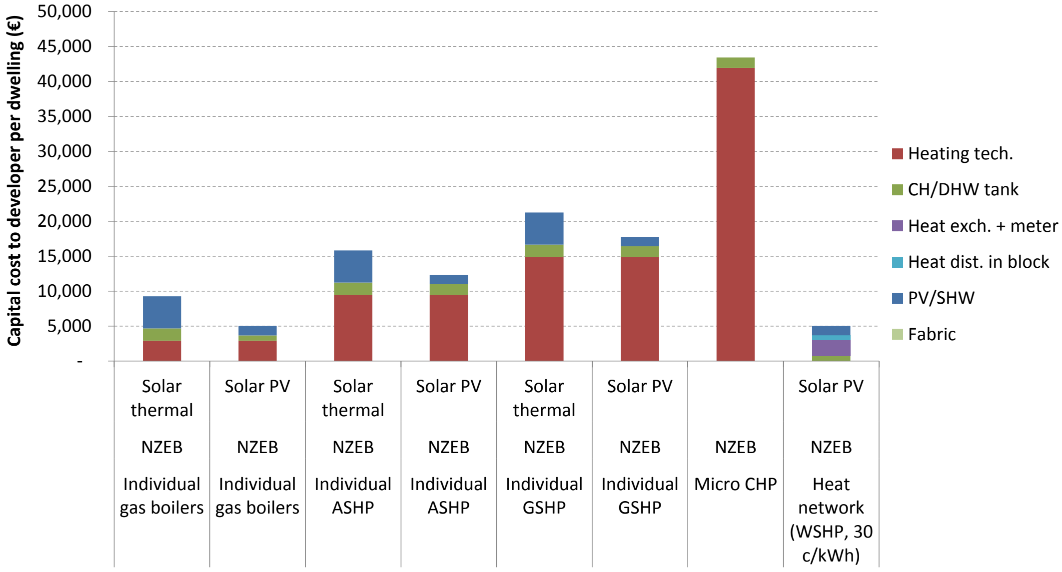

Figure 42: Capital cost to developer: variation with different heating systems (semi-detached house)

Figure 42 shows the upfront costs to the developer for technologies appropriate to a semi-detached house, as set out in Table 17. The economic assessment is based on current prices, in the absence of incentives that could support the deployment of these technologies. Fuel cell micro-CHP is assumed to meet the prescribed levels of on-site energy generation, without the requirement for solar PV or solar thermal.

For semi-detached houses, as for apartments, all heating system options except the heat network option lead to some increase in the upfront cost to the developer relative to the individual gas boiler baseline with solar PV. Comparing other options where solar PV is used where necessary, the additional cost is in the range €6-37k, and is lowest for air source heat pumps, which become a relatively economic option when community heating is not applicable.

As shown in Figure 42, fuel cell micro-CHP currently has very high capital costs. Compared to the other technologies included here, it is at relatively early stage of commercialisation, and the current low production volumes contribute to the high capex. As the market grows, sales prices are expected to reduce dramatically, as indicated in Figure 43 below. If micro-CHP market grows sufficiently for sales prices to come down to around €6,000 per dwelling, it could become a more cost-effective choice than air source and ground source heat pumps (depending on the cost reductions that these technologies could also achieve).

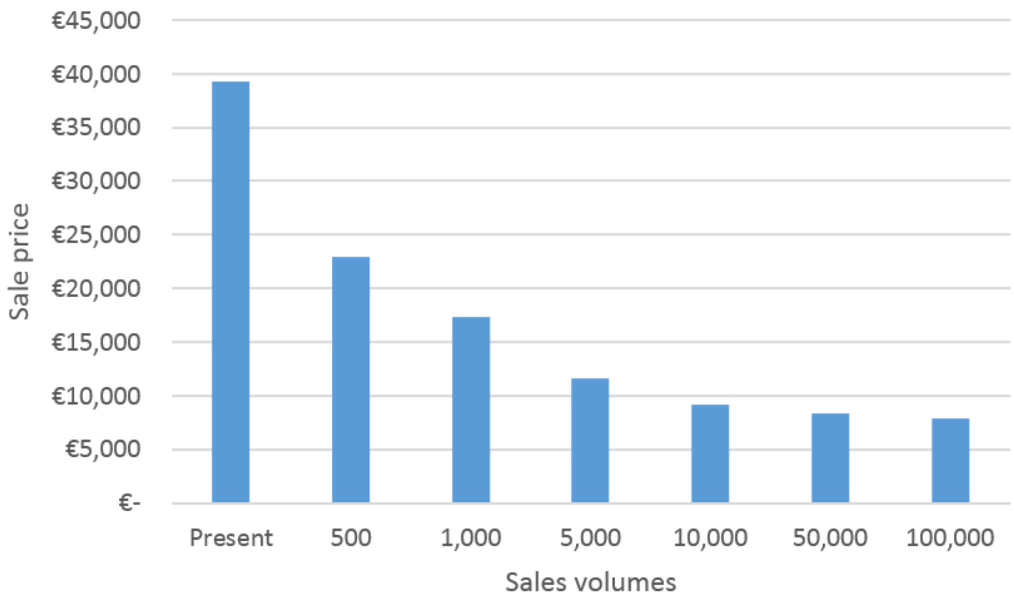

Figure 43: Projected sales prices for increased volumes of 1kW fuel-cell micro CHP[33]

Net present value (including upfront, maintenance and fuel costs): end-user perspective

Figure 44 and Figure 45 show the variation in lifetime net present value (NPV) for different heating technologies, with a fixed level of fabric energy efficiency for mid-floor apartments and semi-detached houses, respectively. The NPV includes upfront, maintenance and fuel costs. In each case the NZEB level of fabric efficiency is applied, since it is likely the NZEB legislation will be in place by the time the new buildings at Clonburris are constructed. All NPV values are negative, since there is overall a net cost; as such, the least negative NPV represents the most cost-effective option on a lifetime basis.

It is noted that, for the numbers shown here, a comparison has been made of the NPV of the various technology options in the absence of any subsidies which may apply, including the RHI for renewable heating (which may apply in future to heat pumps, solar thermal and biomass heating) and a feed-in tariff for solar PV. There is currently no RHI in Ireland, but it is expected that an RHI will be implemented by 2018 if not earlier. However, the scheme may only run to 2020 since the primary objective would be to help Ireland meets its 2020 target of 12% renewable heating by that date, and so it is not clear whether the subsidy will be available for the majority of the development at Clonburris. Solar PV has not up to now been included in the renewable energy support schemes in Ireland (the REFIT 1-3 schemes); however, it is anticipated that a support scheme for solar PV may come into force before 2020. As for the RHI, the primary objective of this scheme may be to help Ireland meet its 2020 targets (in this case the target of 16% renewable electricity by 2020), so it is not clear whether any support would be available for the development at Clonburris.

[33] Roland Berger for the FCH JU, *Advancing Europe's energy systems: stationary fuel cells in distributed generation* (2015)

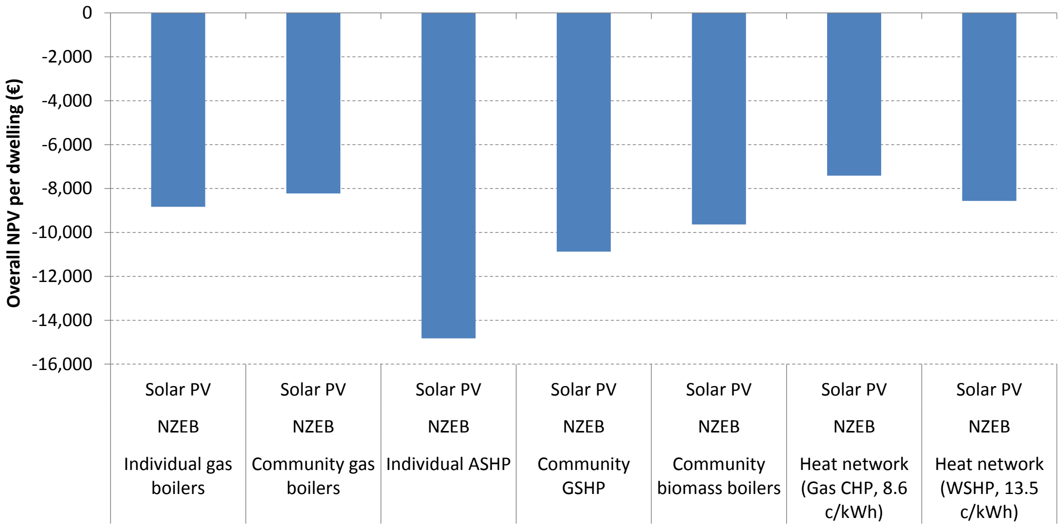

Figure 44: Net present value per dwelling: variation with different heating systems (mid-floor apartment)

For mid-floor apartments, the most cost-effective option on a lifetime NPV basis is the heat network option based on Gas CHP, corresponding to the Fonthill scheme (see section 8), where the price of heat (including upfront, maintenance and fuel costs) is 8.6 c/kWh as found to be required to achieve a 10% IRR for the heat network developer. The heat network option at Fonthill based on WSHP (without RHI), with required price of heat of 13.5 c/kWh, has an NPV more negative by around €1,100, which means it is less cost-effective than the community gas boiler option. This suggests that where a heat network can be viable with a price of heat under approximately 10 c/kWh, as at Fonthill and potentially at Kishoge, this is likely to be the most cost-effective option from the end-user perspective.

Considering the individual and community heating options, it can be seen that the community gas boiler has a less negative NPV, at -€8,230 per dwelling, than the individual gas boiler option. This is due to the lower maintenance costs for a single block-level boiler as compared with multiple gas boilers in each apartment. On a lifetime basis, the community biomass boiler is the most cost-effective option after community and individual gas boilers, at -€9,640 per dwelling, and hence is the most cost-effective low carbon option. The community GSHP option is slightly more costly, at -€10,870 per dwelling, and the individual heat pump option the most costly by a large margin at -€14,830 per dwelling.

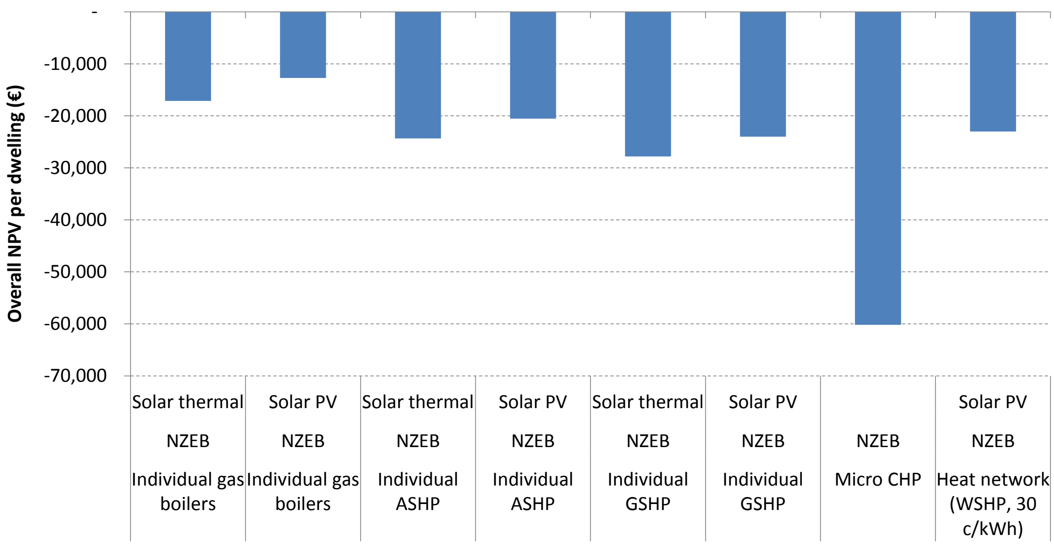

Figure 45: Net present value per dwelling: variation with different heating systems (semi-detached house)

For semi-detached houses, the individual gas boiler (using PV to meet renewable energy requirements) is the most cost-effective option on a lifetime net present value basis, at -€12,970 per dwelling. After individual gas boilers, the air source heat pump is estimated to be the most cost-effective option on a lifetime basis, at -€21,170. As such, the air-source heat pump is the most cost-effective low carbon option for the semi-detached house.

In the case of the semi-detached house, in contrast to the case of the apartment, the heat network option is not the most cost-effective option, with an NPV of -€23,000 per dwelling, more than €10,000 more costly than the individual gas boiler with solar PV baseline. This is due to the very large price of heat required of 30 c/kWh: a heat network including the lower density semi-detached and detached housing, as represented in the Fonthill and Kishoge scheme (see section 8), is significantly less cost-effective than a heat network covering only the high density apartments and non-domestic users at each of the two hubs. This suggests that, while a heat network at one or both of the two hubs could represent a cost-effective option from the end-user perspective for occupants of the apartments at the hubs, a heat network is unlikely to be cost-effective for end-users based in the semi-detached housing away from the hubs.

It is of interest to note that the NPV of the individual ground-source heat pump option is as negative as for the heat network option, suggesting that this is also unlikely to be cost-effective in the absence of an RHI. However, Micro CHP is by far the most costly option, at -€61,070 per dwelling.

Figure 46 and Figure 47 show lifetime net present value (NPV) for different heating technologies when RHI and solar PV FiT tariffs similar to those in place in the UK are applied. No RHI tariff is applied for Micro-CHP, however it should be noted that is likely that some price reduction could be achieved in future, either through subsidies or through greater volumes of global production.

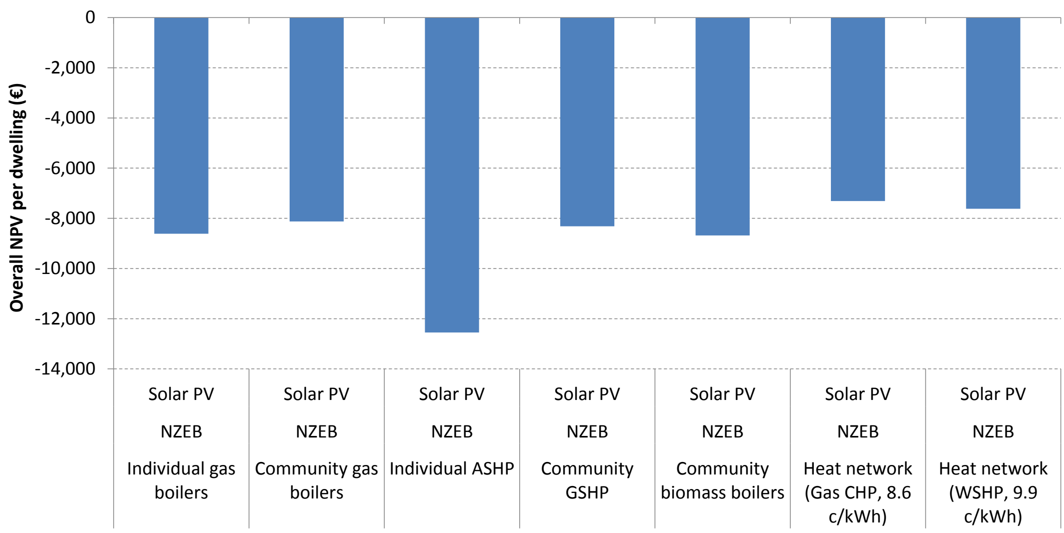

Figure 46: Net present value per dwelling (mid-floor apartment) including revenues from RHI (assumes tariffs are equivalent to the UK)

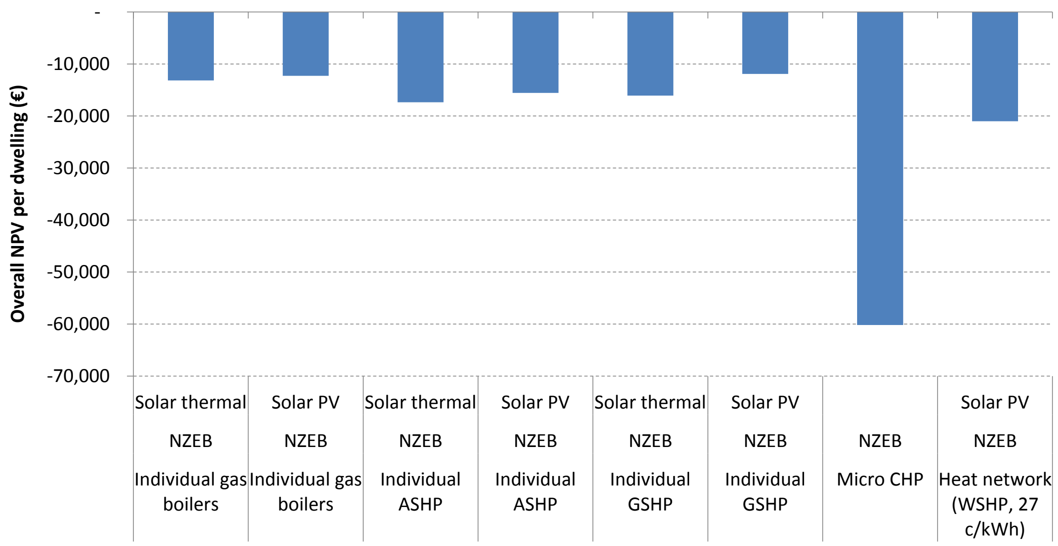

Figure 47: Net present value per dwelling (semi-detached house) including revenues from RHI (assumes tariffs are equivalent to the UK)

When RHI and FiT tariffs are applied, the cost trends are slightly different. While the heat network options are still the most cost-effective option for mid-floor apartments, both community biomass boilers and community ground source heat pumps (-€8,680 and -€8,320) are almost as cost-effective on a lifetime basis, and each of those technologies are competitive with the baseline individual and community gas boiler options. This reflects the fact that the RHI is intended to effectively levelise the lifetime cost of the technologies with the fossil fuel counterfactual.

It is notable that the individual air-source heat pump option is substantially less cost-effective than the other options. It is important to note that the RHI applied here is based on the current UK RHI tariffs; the tariffs for Ireland RHI would be determined through a detailed analysis of the system prices and fuel prices in the Irish context. As such, it would be important to update this analysis using the Irish RHI tariffs.

For semi-detached houses, ground-source heat pumps are found to be the most cost-effective low carbon option on a lifetime basis once the RHI and FiT have been included, at -€11,900 with solar PV, which makes them even more cost-effective than individual gas boilers (-€12,520).

CO_2 savings and cost of savings: environmental perspective

The following figures present the lifetime CO_2 savings and costs of CO_2 savings (defined as the NPV divided by the lifetime CO_2 savings), for the different heating systems and the different dwelling types. CO_2 savings and costs are shown relative to the baseline case: individual gas boilers with Part L 2011 fabric efficiency.

Figure 48 on page 86 shows that biomass boilers with solar PV provide the largest lifetime carbon savings for mid-floor apartments, at more than 9 tonnes of CO_2 per dwelling. The heat network option based on WSHP provides the next largest savings, at more than 6 tonnes per dwelling. The individual air-source heat pump and community ground-source heat pump options save approximately 3.5-4.5 tonnes of CO_2 per dwelling – somewhat lower than the WSHP-based heat network due to the lower heat pump COP and, in the case of the community heat pump, the use of gas to meet peak demand.

It can also be seen in Figure 48 that the heat network option based on Gas CHP leads, over the lifetime of the system, to negative CO_2 savings – that is, an increase in CO_2 emissions versus the gas boiler with solar PV baseline. This is due to the decarbonisation of the grid over the period 2020-2050, which means that electricity generated by gas CHP leads to a net increase in emissions versus grid electricity. This is described further in section 6 and illustrated in Figure 8. This suggests that, for the heat network option to achieve a reduction in CO_2 emissions, the WSHP heat pump (or the biomass boiler) option would be strongly preferable to Gas CHP, despite the Gas CHP being most cost-effective from the end-user perspective.

Figure 49 shows the equivalent savings for semi-detached houses: again the WSHP-based heat network option with solar PV provides the largest carbon savings, at around 14 tonnes of CO_2 per dwelling, closely followed by the individual ground source heat pump with solar PV. The individual air source heat pump option with solar PV saves over 10 tonnes of CO_2 per dwelling. The savings achieved by the ground-source heat pump and air-source heat pump with solar thermal instead of solar PV are lower, at around 10 and 8 tonnes respectively. However, micro CHP brings savings of 9 tonnes per dwelling, even without solar PV or solar thermal.

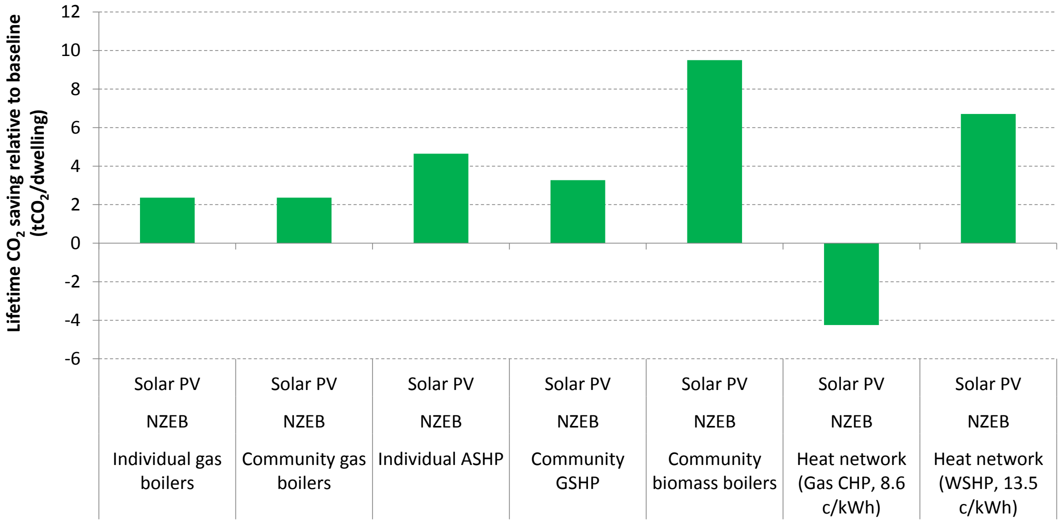

Figure 48: Lifetime CO_2 savings: variation with different heating systems (mid-floor apartment)

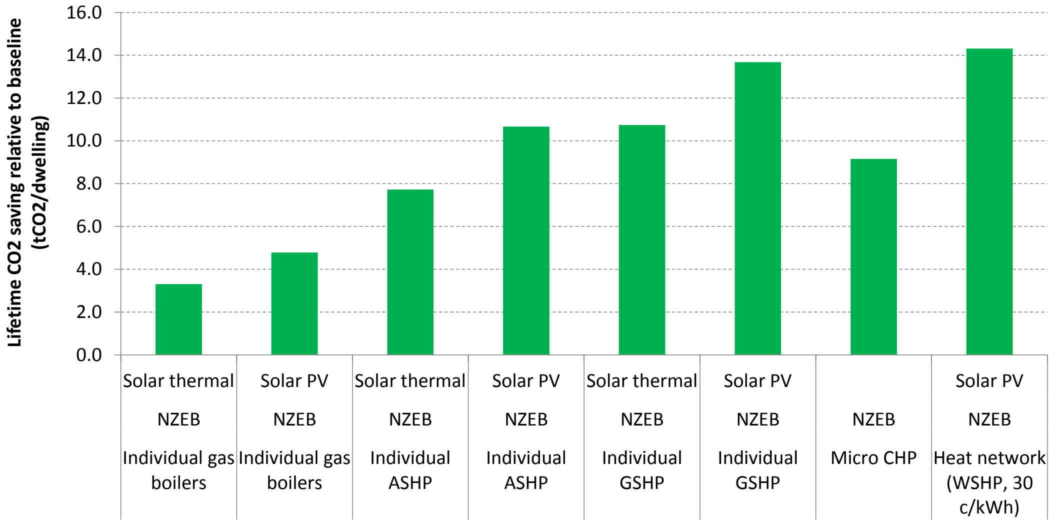

Figure 49: Lifetime CO_2 savings: variation with different heating systems (semi-detached house)

Figure 50 and Figure 51 show the cost of CO_2 savings measured relative to the Part L 2011, individual gas boiler with solar PV baseline. Note that the figures include the cost and CO_2 savings associated with the NZEB thermal efficiency level, as well as the heating technology.

Figure 50 shows that, of the lowest carbon options outlined above for mid-floor apartments, the heat network based on a WSHP is the most cost-effective in terms of the cost of CO_2 saved, at €190/tCO_2. The community biomass boiler is the next most cost-effective, at €250/tCO_2. This result should be considered alongside the several disadvantages of biomass-based schemes, as described in Section 6.5.1, which include the air quality impacts, potential security of supply risks and the requirement for frequent fuel delivery on trucks.

The CO_2 savings from the community GSHP option are significantly more costly, at more than €1,000/tCO_2, due to the large upfront cost of the heat pump. The individual ASHP option is the most expensive, at more than €1,600/tCO_2, due to the very large upfront cost of providing individual heat pumps to each dwelling.

Figure 51 shows the equivalent costs of carbon savings for semi-detached houses. Note that the Micro CHP option is not presented on the chart for clarity, as the cost of CO_2 savings associated with this option is very large, more than €5,000/tCO_2. It can be seen that, since solar thermal is assumed to be part of the baseline Part L energy efficiency package, the NZEB individual gas boiler option with solar PV has a negative cost of carbon savings, compared to the baseline, despite the additional costs of the NZEB energy efficiency package. This is largely due to the lifetime savings possible through the displacement of grid electricity, with electricity generated onsite.

Among the low carbon heating options, the air source heat pump with solar PV is the most cost-effective low carbon option, in terms of the cost of CO_2 saved, at €640/tCO_2 relative to the baseline option (which assumes solar thermal is used in Part L energy efficiency, rather than solar PV). This is closely followed by the heat network option based on WSHP at €650/tCO_2. The cost of CO2 savings for the ground source heat pump with solar PV option is €760/tCO_2. The high cost of CO_2 savings from all the low carbon options in the case of the semi-detached house suggests that it will be more challenging to achieve carbon emissions reductions in semi-detached houses than in the apartments, as this is likely to entail a high cost to the end-user.

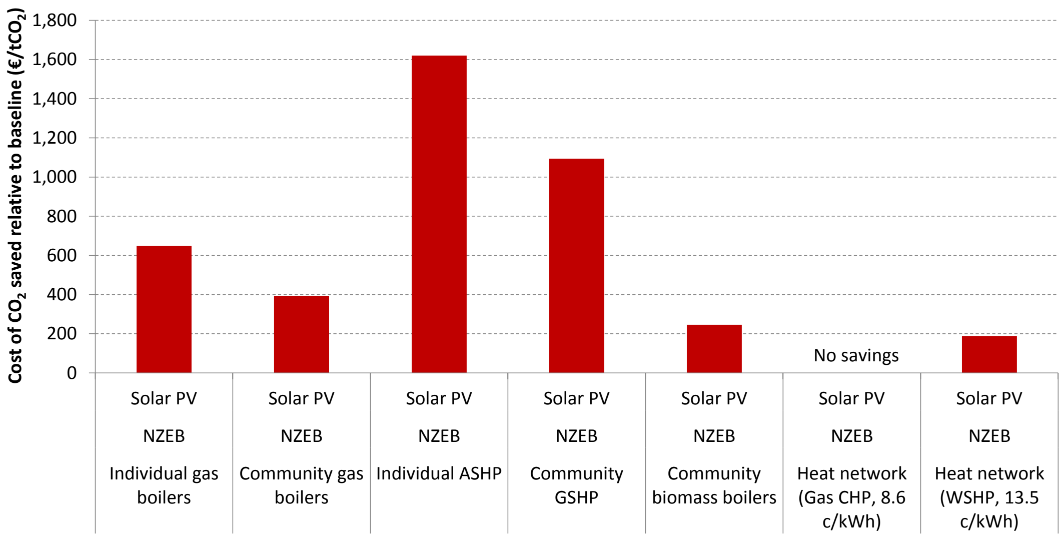

Figure 50: Cost of CO_2 savings: variation with different heating systems (mid-floor apartment)

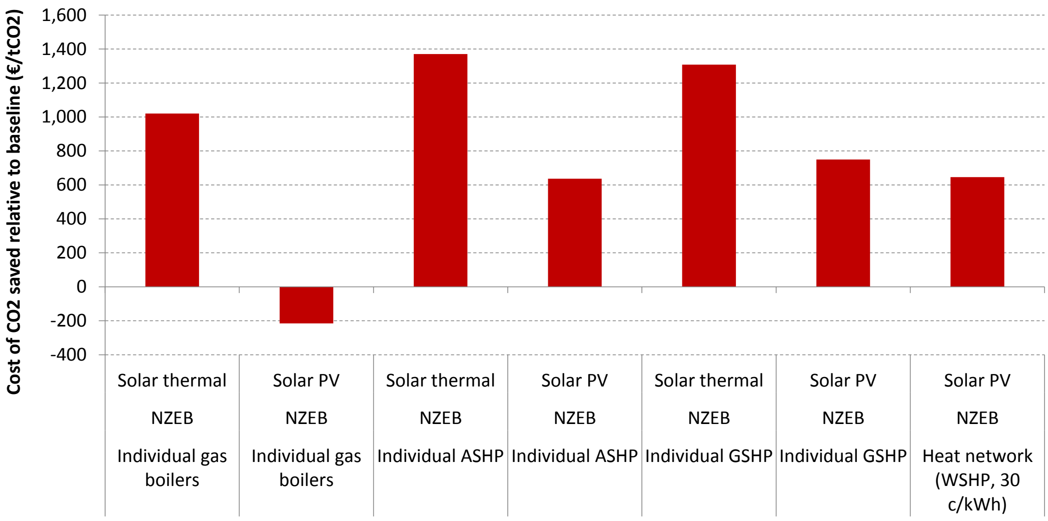

Figure 51: Cost of CO_2 savings: variation with different heating systems (semi-detached house)

10 Energy planning for schools

10.1 Overview of planned Clonburris schools

The latest high-level land use plans for the SDZ include several sites throughout the area (shown in brown in the schematic in Figure 52) which are to be designated as "community hubs" where new schools are likely to be located alongside parks and other social and civic infrastructure. Site areas have yet to be defined.

These initial plans align well with the 2008 Local Area Plan, which envisaged eight potential sites for a total of ten schools in the Clonburris LDZ.

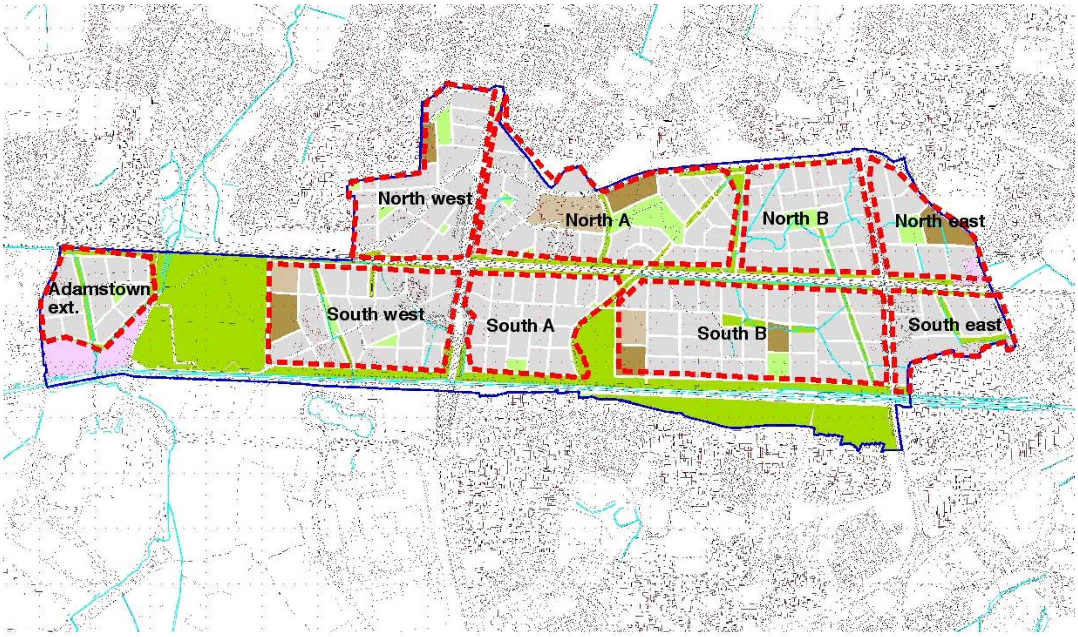

Figure 52: Schematic showing basic structure of Clonburris and planned land use

10.1.1 Characteristics and energy use for new schools

Around half of primary schools in Ireland have between 100 and 500 pupils, with the 100-200 range being the most frequent in Ireland. The majority of secondary schools have over 300 pupils, with 75% of secondary schools having at least this many pupils.

A typical primary school could have a floor area of around 2,300m^2, and a secondary school could be as much as ten times larger.

Figure 53 shows some examples of the uses of energy in schools. The graphic on the left shows the percentages of energy used for different activities in UK schools. The graphic on the right shows the possible energy demand for a new build primary school, and how this is shared between different use categories. In both cases, energy demand for space heating accounts for over half of the total energy demand; this means that for new schools, ensuring minimal heat loss from the building will be one of the most important factors in achieving a low overall energy demand.

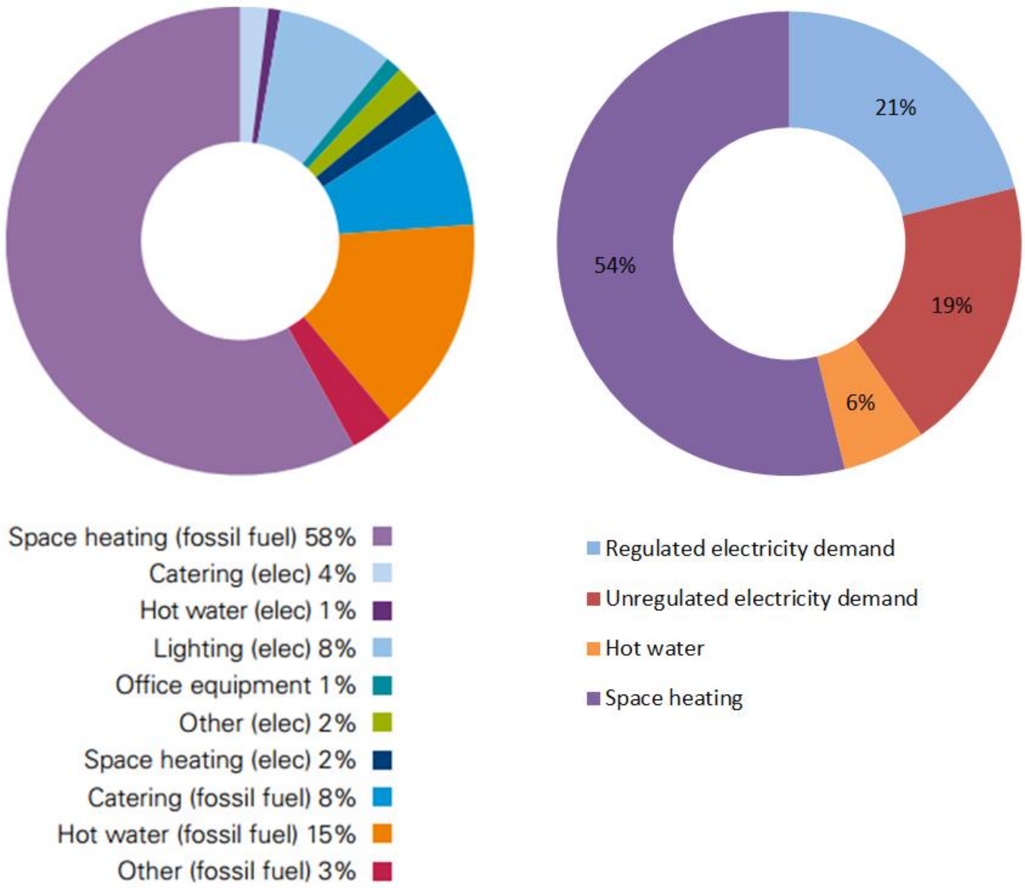

Figure 53: Percentages of energy use in schools (left, based on Carbon Trust analysis for primary and secondary schools[34]) and simplified energy demand share for a primary school (right, based on estimated demand for a primary school meeting "nearly zero energy" energy efficiency standards [35])

Like residential buildings, new schools are likely to be required to meet certain energy efficiency requirements, as part of the transition to "Nearly Zero Energy" Buildings. This may involve a significant reduction to energy demand, compared to existing schools, and in some cases the use of onsite renewable energy sources may also be appropriate.

The Department of Education and Skills has already incorporated low energy design and energy efficiency in school design, through a combined focus on using low energy technologies, and maximising natural resources (i.e. via passive solar design, natural daylight, natural ventilation etc.). Technical guidance documents are available from the Department for the design and building of schools which provide information on how to use different technologies to achieve low energy design; schools built in accordance with these documents are capable of being more than twice as energy efficient as schools built to best international practice. The potential use of renewables is maximised in school design, but

[34] Carbon Trust, Schools Sector Overview: https://www.carbontrust.com/media/39232/ctv019_schools.pdf

[35] Aecom for the DECLG, 2013, Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-Residential Buildings

it is critical that demand for energy is minimised before further investment in renewable energy applications takes place.[36]

The following section considers a number of energy provision options for schools in the SDZ, and their possible advantages and disadvantages.

10.2 Options for energy provision in schools

10.2.1 Solar photovoltaic panels

Solar panels could be installed in an accessible location (either the roof, if accessible, or at another accessible location such as a school garden or field). An example of solar PV installation at a primary school is shown in Figure 54.

Advantages for school installation:

- Ideal opportunity for hands-on education about renewable energy.
- Ease of installation and few planning issues (installation can be over a weekend).
- Low maintenance.
- High returns through displacement of electricity from the grid (and from possible feed-in tariffs) could make an attractive financial case for the school, or for private investors
- Roof space is likely to be available.

Figure 54: 45 kW solar PV panels installed at Butlers Hill Infant & Nursery school, Nottingham in 2014[37]

Disadvantages for school installation:

- Large areas required for significant CO_2 impact.
- Without electric heating technology, solar PV does not contribute to meeting a school's demand for heat, which is the largest component of energy demand.

[36] DECLG, 2012, Towards Nearly Zero Energy Buildings in Ireland
[37] http://www.customsolar.co.uk/blog/butlers-hill-infant-nursery-school-solar-installation-nottingham/

10.2.2 Ground source heat pump (with photovoltaic panels)

Ground-source heat pumps (GSHPs) were introduced in Section 6.5.2. GSHPs use heat collectors which are buried in the ground, either in the form of horizontal loops, "slinkies" or vertically drilled boreholes, depending on the space available and the type of soil. These options are shown in the diagram in Figure 55 ("pond loops" are further option that can be used in water).

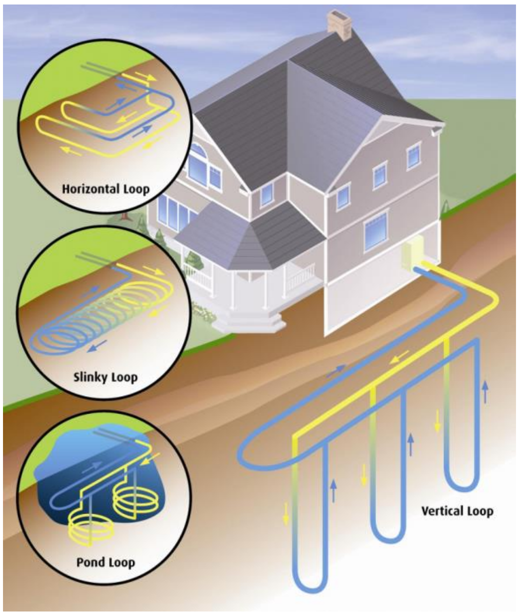

Figure 55: Options for ground source heat pump heat collectors[38]

Ground source heat pumps work best with low temperature underfloor heating systems, and therefore are most suitable for new build schools.

If photovoltaic panels (PV) are also installed, the low carbon electricity generated on-site could provide a share of the heating needs, by powering the ground-source heat pump.

Advantages for school installation:

- Potential for low carbon heat, in combination with PV (and/or as the grid decarbonises).
- Low maintenance and running costs.

Disadvantages for school installation:

- Up-front costs are high and depend on ground conditions.
- Large areas required for installation of boreholes.
- Likely to require a gas boiler ("back boiler") as well to meet peak heat demand (e.g. to heat water).

10.2.3 Biomass boiler

A biomass boiler burns wood pellets, chips or logs to heat hot water and power a central heating system.

[38] http://www.spiritsolar.co.uk/heat-pumps/heat-pump-overview/ground-source-overview/

Advantages for school installation:

- Potential to provide very low carbon heat.
- Relatively cost-effective (wood is an affordable fuel).
- Opportunity for hands-on education around different sources of biomass, and their relative merits in terms of sustainability.

Disadvantages for school installation:

- Requirement for regular fuel deliveries and storage (large footprint).
- Some negative impacts on air quality.
- Likely to require a gas boiler ("back boiler") as well to meet peak heat demand (e.g. to heat water).

Section 10.3 considers the economic and environmental costs and benefits of the four options for energy provision in schools in the Clonburris SDZ.

10.3 Estimated economic and emissions impacts of energy provision options

Table 18 shows the energy demand for an illustrative new build primary school, based on calculations by AECOM[39] for DECLG. This assumes a significant reduction in energy consumption, compared to the existing stock of school buildings, and reflects the transition towards "Nearly Zero Energy" buildings.

Table 18: Annual energy demand for an illustrative primary school

Energy demand	Space heating	Hot water	Regulated electricity demands (mainly lighting)	Unregulated electricity demands
kWh per m^2 of floor space per year	33	4	13	12
MWh per school per year (assumes 2,300 m^2 floor space)	77	8	30	27

Table 19 shows the economic and emissions impacts of the various options. These are calculated based on the energy demand figures in Table 18, relative to a baseline case where the heating is provided by a gas boiler, and electricity demand is entirely met by grid electricity. The table presents the case where there are no Feed-In Tariffs or other incentives that might support the installation of these technologies in schools.

[39] AECOM, *Report on the cost-optimal calculations and gap analysis for buildings in Ireland under Directive 2010/31/EU on the energy performance of buildings (recast); Section 1 - Residential buildings* (2013)

Table 19: Economic and CO_2 emissions impacts of energy provision options for an illustrative primary school

	PV	Ground-source heat pump + PV	Biomass boiler
Sizing	Designed to meet all on-site electricity demand	Meets over 90% of heat demand, peak demand provided by 100kW$_{th}$ gas boiler	Meets approx. 70% of heat demand, peak demand provided by 100kW$_{th}$ gas boiler Approx. 50% of electricity demand met by CHP.
Capital cost premium (€)	69,170	144,480	29,920
Annual fuel cost savings (€)	6,940	10,780	2,204
Payback time (years)	10	13	14
CO_2 emissions savings (kg CO_2 / year)	25,790	37,890	16,650

The results indicate that PV is the most cost-effective option for installation in new schools, with the least negative NPV after 20 years, and the shortest payback period relative to a school with no low carbon heat or power technology. In addition, it provides the second highest CO_2 emissions savings of the four options considered here. If a ground source heat pump was also installed alongside PV panels, this could provide an even greater saving in emissions, and the additional fuel cost savings provided would mean that, despite the high capital cost, payback could be achieved in only 13 years.

11 Sustainable transport options

A range of measures could be taken to maximise transport sustainability in the Clonburris SDZ. These measures could enable improved sustainability by either facilitating access to sustainable transport options (such as walking, cycling and public transport), or by minimising emissions arising from transport to and from the development. Consideration should be given to measures that address the following aspects[40]:

- Proximity and accessibility to public transport, i.e. locating the main building entrances close to as many useful public transport departure points as possible
- Accessibility of amenities
- Limiting the number of car parking spaces
- Travel planning, including site specific travel assessment, and the development of a travel plan including measures to encourage the use of sustainable modes of transport
- Alternative modes of transport – this could include measures such as:
  - Measures to facilitate cycling in the area
  - Secure, convenient cycle storage
  - Improved provision of public transport
  - Provision of electric recharging stations
  - Provision of a car club

The next section explores options to encourage **alternative modes of transport** in more detail.

11.1 Supporting alternative modes of transport

Developers could encourage the use of various alternative modes of transport through a wide range of measures. Table 20 sets out options that could A) encourage mode shift in residents / building users towards options such as walking, cycling, and public transport, and B) support more sustainable car use, either through car clubs (reducing car ownership and usage) or replacement of petrol/diesel cars with electric cars.

Details and examples for car clubs and electric charging points are provided below.

11.1.1 Car clubs

Ratios of overall benefits to costs for car clubs range from **1.2 – 5.7** (based on 5 years of operation in various UK cities, and accounting for the benefits of reductions to carbon emissions and air pollution as well as economic benefits)[41].

Including electric vehicles as part of a car club provides the opportunity for further emission reductions but requires a certain level of charging infrastructure, and arrangements for charging must be defined.

Examples

- Nottingham City Council has formed a partnership with City Car Club to launch new car club sites, offering a pool of shared cars which includes electric and hybrid vehicles.
- Go Car is a car-share service operating in Dublin.

[40] BREEAM International New Construction 2016
[41] CarPlus, 2016, The Economic Case For Car Clubs (http://www.carplus.org.uk/the-economic-case-for-car-clubs-benefit-cost-ratio-tool/)

11.1.2 Electric charging points

Installation of domestic charging points will support the use of electric vehicles, and could also be used by car club electric vehicles (80% of all EV annual energy requirements are likely to be supplied through the Consumer's own Domestic socket).

ESB will install the first 2,000 domestic charging points for free, and also have a network of over 1,200 public charging points across Ireland and Northern Ireland.

Table 20: Options for supporting sustainable modes of transport

A) Mode shift to sustainable transport options	B) More sustainable car use
Provisions for cyclists and pedestrians[42] • Ample bicycle storage • Cycle paths and contributions to wider local cycling network (i.e. through negotiation with local authorities) • Low speed limits on private roads	**Car clubs** • Members share the use of a locally based fleet • Facilities to encourage building users to sign up; marketing material to raise awareness • Priority spaces for car sharers
Public transport • Developers could liaise with local bus companies to ensure that: a) Sufficient services are available for building users / residents b) Vehicles serving local routes operate on clean, efficient technologies	**Electric cars** • Charging points provided alongside parking facilities • Enables the use of electric cars in place of petrol / diesel cars • Demonstrable CO_2 savings e.g. through provision of renewable electricity

[42] Sustrans, 2016 http://www.sustrans.org.uk/what-you-can-do/change-your-street/ten-simple-ways-make-your-street-safe-and-green-place-live (Accessed November 2016)

12 Planning policy

Planning policy is a powerful tool through which the Council's overarching objectives and priorities can be realised. Indeed, realising the energy project opportunities described in this masterplanning study is likely to require an update to the planning framework used by SDCC to grant permission for new developments.

Of particular relevance to the projects described here, planning policy could be applied, and may be necessary, to achieve the following:

- Ensuring building fabric efficiency standards go beyond existing regulations, e.g. designing to NZEB standards before this becomes part of the national legislation;
- Ensuring developers of new buildings connect to a local heat network.

In this section, examples taken from the London Plan[43] are highlighted, of how planning policy can be used to achieve these objectives.

Ensuring building fabric efficiency beyond existing regulations

Since 2010, the London Plan set out objectives to ensure new developments are built to higher efficiency standards than the existing building regulations. The Plan's *Policy 5.2: Minimising Carbon Dioxide emissions*[44] states that:

"The Mayor will work with boroughs and developers to ensure that major developments meet the following targets for carbon dioxide emissions reduction in buildings. These targets are expressed as minimum improvements over the Target Emission Rate (TER) outlined in the national Building Regulations leading to zero carbon residential buildings from 2016 and zero carbon non-domestic buildings from 2019."

The targets referred to, for the case of residential buildings, are shown in Table 21. Similar targets were applied to non-domestic buildings.

Table 21: CO_2 emissions reduction required for new residential buildings in the London Plan

Year	Improvement on 2010 Building Regulations
2010 – 2013	25 per cent
2013 – 2016	40 per cent
2016 – 2031	Zero carbon

The Plan also specified that development proposal must include an energy assessment to demonstrate how the appropriate target will be met within the framework of an 'energy hierarchy, prioritising energy demand reduction first, followed by efficient energy provision, followed by the use of renewable energy sources. It was stipulated that the energy assessment should include:

"*as a minimum… :*

[43] https://www.london.gov.uk/what-we-do/planning/london-plan/current-london-plan (Accessed November 2016)
[44] https://www.london.gov.uk/what-we-do/planning/london-plan/current-london-plan/london-plan-chapter-five-londons-response/policy (Accessed November 2016)

a) *a calculation of the energy demand and carbon dioxide emissions covered by Building Regulations and, separately, the energy demand and carbon dioxide emissions from any other part of the development, including plant or equipment, that are not covered by the Building Regulations (see paragraph 5.22) at each stage of the energy hierarchy*
b) *proposals to reduce carbon dioxide emissions through the energy efficient design of the site, buildings and services*
c) *proposals to further reduce carbon dioxide emissions through the use of decentralised energy where feasible, such as district heating and cooling and combined heat and power (CHP)*
d) *proposals to further reduce carbon dioxide emissions through the use of on-site renewable energy technologies*."

Similar planning policy could be applied to new development on the SDZ. For example, the indicative phasing described in section 4 suggests that the residential development on the site could begin as early as 2017-18. In this case, this early development could be undertaken before NZEB becomes a legislated requirement in Ireland. In this case, requirements such as those quoted above could be used to future-proof the building fabric efficiency level – for example, aligning it with the expected level of Ireland's NZEB definition. This would ensure the early development is built to a similar standard as the later phases which, just several years later, would be required to meet NZEB under national law.

Ensuring developers of new buildings connect to a local heat network

Suitable planning policy is also critical in ensuring the successful delivery of a heat network. As demonstrated in this energy masterplanning study, the viability of a heat network rests on the presence of a critical density of heat customers, in order that the large capital investment in the required infrastructure can be justified by a guarantee of sufficient future heat sales.

For Clonburris SDZ, it is feasible that all new development connects to a heat network, since the vast majority of the development will be new build, but this is not guaranteed. A viable heat network must be attractive to the end-user in terms of a competitive price of heat, but even then there is no guarantee – without strong planning policy – that the user will connect to the network. For example, many building developers have highly standardised 'templates' for building services, which they are capable of delivering at low cost and with little to no new design work required, and which are fully consistent with building regulations. Such developers would typically prefer to implement this template unless the heat network alternative strategy can be shown to have both lower upfront cost and lower lifecycle cost than the counterfactual option – and even then, connection is not guaranteed.

As such, planning policy is a crucial tool in removing much of this uncertainty to the heat network developer, typically by placing the burden of proof on the building developer to make the case that connection to the heat network is not economically competitive versus the counterfactual option.

An example of planning policy for this purpose is Policy 5.6[45] of the London Plan: *Decentralised energy in development proposals*. This policy requires that:

[45] https://www.london.gov.uk/what-we-do/planning/london-plan/current-london-plan/london-plan-chapter-five-londons-response/policy-56-decentralised (Accessed November 2016)

"*Major development proposals should select energy systems in accordance with the following hierarchy:*

1. *Connection to existing heating or cooling networks;*
2. *Site wide CHP network;*
3. *Communal heating and cooling."*

The policy requires that development proposals should consider planned district energy networks, as well as existing networks, and that where planned networks are identified in the local area, proposals "should be designed to connect to these networks".

Planning policy such as this would be of great importance should a heat network become planned for development at Fonthill and/or Kishoge, to ensure that any new development is designed to connect to the network where economically viable.

An example of the more detailed wording used for this purpose can be found in Islington Council's *Development Management Policies Development Plan Document*[46] in Policy DM 7.3 on 'Decentralised Energy Networks'. The full wording for this Policy is provided in Box 1 below for reference.

[46] Islington's Local Plan: Development Management Policies (June 2013)

Box 1: Islington Council's Development Management Policy DM 7.3 on Decentralised Energy Networks

A. All major developments are required to be designed to be able to connect to a Decentralised Energy Network (DEN). Minor new-build developments should be designed to be able to connect wherever reasonably possible.

B. Major developments located within 500 metres of an existing DEN, and minor new-build developments located within 100 metres, will be required to connect to that network, including provision of the means to connect to that network and a reasonable financial contribution to the connection charge, unless a feasibility assessment demonstrates that connection is not reasonably possible.

C. Major developments located within 500 metres of a planned future DEN, which is considered by the council likely to be operational within 3 years of a grant of planning permission, will be required to provide a means to connect to that network and developers shall provide a reasonable financial contribution for the future cost of connection and a commitment to connect via a legal agreement or contract, unless a feasibility assessment demonstrates that connection is not reasonably possible.

D. Where connection to an existing or future DEN is not possible, major developments should develop and/or connect to a Shared Heating Network (SHN) linking neighbouring developments and/or existing buildings, unless it can be demonstrated that this is not reasonably possible.

E. Where connection to an existing or future DEN is deemed possible under the above policy, major developments are required to detail a preferred energy strategy and an alternative energy strategy within their Energy Statements. The preferred energy strategy shall be based on connection to a DEN and shall be enacted, unless it is not reasonably possible to connect to a DEN, in which case the alternative energy strategy shall be enacted.

F. The council will support the development of decentralised energy networks and energy centres in principle, subject to meeting wider policy requirements, including on design (Policy DM2.1 and Policy DM2.3) and air quality (Policy DM6.1).

Supporting text:

7.9 Part A of Policy DM7.3 requires developments to have the ability to connect to a DEN, which means that developments have the ability to be connected to a network if/when such a network becomes available in the future, rather than necessarily connecting at the time of construction. Whether minor developments can reasonably be designed to be able to connect to a DEN will be assessed by the council, taking into account a range of factors, including size, location, use and design of the development. Specific design standards to enable connection and future connection will be set out in the Environmental Design SPD.

7.10 All major developments within 500 metres of an existing or planned DEN, or minor new build developments within 100 metres of an existing network, are required to submit a feasibility assessment of connection to that network, to determine whether connection is reasonably possible. The council, or relevant Energy Service Company, will provide relevant information to inform the feasibility assessment, including an assessment of the approximate cost of connection. Where connection is not considered technically possible or is not considered possible for non-technical reasons, including financial viability, then major applications must enact their alternative energy strategy. Feasibility assessments should consider a range of factors, including: the size of the development, and the heat load and energy demands; the distance to network pipes; physical barriers e.g. roads and railways, and other developments in the vicinity that may also be required to connect to the network.

7.11 The CO2 reductions anticipated from connection shall be assessed and agreed by the council. Other measures proposed to contribute to the relevant CO2 reduction target shall be complementary with network connection technologies and/or with SHN technologies, in order to achieve maximum reasonable CO2 reductions.

7.12 The evidence base includes an assessment of the financial viability of achieving a 40% reduction in CO2emissions without connection as well as a 50% reduction in CO2 emissions with connection (relative to 2006 Building Regulations Part L). However, where it can be demonstrated that the cost of an energy strategy involving connection to a network to achieve the 50% target (or equivalent, see below) significantly exceeds the cost of achieving a 40% CO2 reduction (or equivalent, see below) without connection, and that this presents problems with financial viability, this will be taken into account in assessing the feasibility of network connection.

7.13 Where connection of a major development to a future DEN is feasible, developers are required to commit to connection via a legal agreement; this will include provision for a financial payment to the council to enable connection. Within the legal agreement a cut-off point will be defined, which will be the latest point at which a decision can be made in relation to network connection. If at this time it is not possible to agree connection to a network, due to the network being incomplete, the alternative energy strategy will be enacted.

7.14 The council's CIL charge includes provision for investment in DENs in the borough. This is intended to increase the size of the network to bring more sites within a reasonable connection distance. The financial contribution towards site connection secured via a legal agreement is a separate cost and is not covered by CIL.

7.15 Where connection to an existing or planned decentralised energy network is not possible, all major developments should fully explore any opportunities to support the establishment of new decentralised energy networks through developing and/or connecting to a SHN with neighbouring existing buildings or new developments and take action to deliver these wherever feasible. Such shared networks are likely to be more efficient and may enable use of low or zero carbon technologies, such as Combined Heat and Power.

7.16 Whether development of or connection to a SHN is reasonably possible will be assessed by the council, based on a range of factors, including: the size and nature of the heat load within the development and neighbouring communally heated sites; the distance between the sites; any physical barriers e.g. roads and railways; the practicality of connection, including willingness of existing building owners, timing of schemes and any other legal or management issues, and the carbon reduction likely from such a connection, including the feasibility of use of low or zero carbon technologies, such as CHP.

7.17 Where a SHN is created, any CO2 reductions achieved by the development site, or by existing buildings which are connected to the network as a result of the development, shall contribute to the achievement of the development's minimum 40% total CO2 reduction target, in comparison to a building which meets Part L Building Regulations 2006 (or equivalent, see below).

7.18 Where connection to an existing or future DEN is deemed possible under the above policy, major developments are required to detail a preferred energy strategy and an alternative energy strategy within their Energy Statements. The preferred energy strategy shall be based on connection to a DEN and detail at least a 50% reduction in CO2 compared with total emissions from a building that complies with 2006 Building Regulations Part L (refer to the Core Strategy), or at least 40% compared with total emissions from a building that complies with 2010 Building Regulations Part L (an equivalent reduction). The alternative energy strategy, based on no connection to a DEN, shall detail at least a 40% reduction compared with total emissions from a building that complies with Building Regulations Part L 2006 or at least 30% compared with total emissions from a building that complies with 2010 Building Regulations Part L (an equivalent reduction). The preferred energy strategy shall be enacted, unless it is not reasonably possible to connect to a DEN, in which case the alternative energy strategy shall be enacted.

7.19 All financial sums shall be paid to the council and index-linked. Reasonable legal fees will also be payable.

13 Delivery plan for a heat network at Clonburris

13.1 Description of ownership models

There are a range of potential delivery models and financing structures that could be used to deliver a heat network at Clonburris. The delivery models that are typically employed for heat networks involve contractual arrangements between a project sponsor (for example a developer or the local authority) and one or more service providers, which provide the various elements of design, construction and operation of the system. The most appropriate model will depend on the circumstances of a particular scheme, including the balance of existing and new build buildings expected to connect to the system, the strength of the business case (e.g. the rate of return on investment in the scheme) and the appetite of various stakeholders to engage with delivery of the scheme.

The most commonly used contractual arrangement can be summarised as follows[47]:

- **Energy service company (ESCO) / utility** – An expert provider, such as an ESCO or utility, undertakes to design, build, finance and operate the heat network and to supply heat to customers within the area that become connected to the network.
- **Wholesale supply of energy (design, build and operate contract)** – A project sponsor contracts with a single provider to design, build, own and operate the heat network and to sell wholesale energy to the sponsor. The sponsor sells energy on to retail consumers (and may be a consumer itself).
- **Network delivery and operation** – The project sponsor contracts with multiple providers to design, build, operate and maintain a heat network, but the sponsor remains the owner of the assets. The sponsor enters into heat (and potentially electricity) supply agreements with consumers and may also handle fuel purchasing.

The role for SDCC within these delivery models could also take a variety of forms. These include:

- **Heat consumers** – Council-controlled buildings can provide significant heat demand. By agreeing to connect its buildings within the local area to a heat network SDCC could help to provide the heat demand needed for the heat network business case to be viable.
- **Convening and influencing** – SDCC could influence developers, landlords and tenants to connect to the heat network using the range of planning and development control powers at its disposal, as well as influence as a land and property owner.
- **Contracting party** – SDCC could be more directly involved in driving establishment of a heat network. This could include provision of project finance in some form (see below) or by contracting with an ESCO that provides a full design, build, finance and operate (DBFO) solution (even in the latter case, although the local authority maintains no ownership of heat network assets, it may provide some form of financial contribution).
- **Joint venture** – Rather than entering into a contractual arrangement with an ESCO, the local authority could invest in a special purpose vehicle as a corporate joint venture, alongside an existing ESCO or other investors. The project delivery vehicle will then deliver the heat network (potentially

[47] Based on 'District heating manual for London', GLA (2013)

contracting elements out to third parties) and supply heat and power to consumers.

A number of the potential roles for SDCC described above involve provision of a financial contribution of some form. Broadly the options for how SDCC could apply funding can be categorised as follows:

- Grant funding (could be provided by SDCC or another public sector body, including national government or European Commission funding sources)
- Direct expenditure on public assets (e.g. buildings or land), including provision (sale or lease) of land and buildings
- Debt finance, in the form of low interest rate loans
- Equity investment in project vehicles

The applicability of the various contracting structures described above to the Clonburris SDZ development and the implications for the role of SDCC are discussed further in the following.

13.2 Delivery models for a heat network at Clonburris SDZ

On the basis of the analysis in this energy masterplanning study, there may be opportunities for a heat network to be developed at Clonburris through a fully private sector delivery model. The scheme option focusing on the dense development Fonthill hub, and to a lesser extent the scheme option at the Kishoge hub, could provide opportunities to develop a heat network offering a commercial rate of return of >10%, if the level of development expected is realised.

In this case, the key role for SDCC would be to ensure that the planning policy applied to new development at the SDZ is designed to ensure the highest level of connection to the network as possible, as described in section 12. The Council could also promote the project among local stakeholders and influence landowners and tenants in favour of connecting to the network, and in favour of granting the necessary wayleaves to roll out the infrastructure. The Council should also ensure that public and community buildings on the site are designed to connect to the network, and if possible located to ensure a favourable impact on the economics of the heat network.

In the absence of a driver for the private sector to deliver the heat network, or as an alternative in any case, SDCC could provide this driving force. An SDCC-led delivery model could take any of the contracting arrangements described in the prior section. However, a model which transfers the technical delivery and operational risk from SDCC is likely to be preferred given that SDCC does not have prior experience of delivering this type of energy project. On this basis, it is assumed that the most likely delivery models involving SDCC would be to:

1. Enter into a contract with an ESCO or utility to **design, build, and operate, but not to finance** the district heating system. In this case, the full investment for the project is met through public funds.
2. Enter into a contract with an ESCO or utility to **design, build, finance and operate** the district heating system. The level of financing that the ESCO will provide in this case is likely to be limited to a level at which they are able to make a commercial return on their investment, i.e. through sale of energy services (heat, electricity and any additional financial incentives, such as the RHI) and connection agreements with developers (i.e. charges for connection of buildings to the network).

In case (2), the investment shortfall will need to be provided by public sector funding. A number of potential sources of public sector funding can be identified:

- **European Regional Development Funding** – European funding aimed at innovation and knowledge transfer, enterprise, sustainable development and building sustainable communities.
- **Local authority investment** – SDCC's investment is most likely to take the form of provision of land (e.g. for an energy centre) and low-cost debt finance.
- **National government funding.** There is currently no capital funding scheme in Ireland dedicated to the support of heat networks. As described throughout this report, an RHI is likely to be launched in 2017, and heat networks based on heat pumps biomass would be expected to be eligible; however, this will take the form of an ongoing payment and, while it will improve overall project economics, it is unlikely that it will provide upfront capital support. Funding could potentially be available through the Better Energy Communities[48] scheme, but this is targeted at smaller projects (<€75k) and those focusing on energy efficiency. As an example of a targeted scheme to support heat networks, the UK government's Heat Network Delivery Unit announced in 2015 the availability of a ≈£300m capital fund to support projects that have been identified through the heat network master planning and feasibility stages.

The general form of the financing model is summarised in the diagram below.

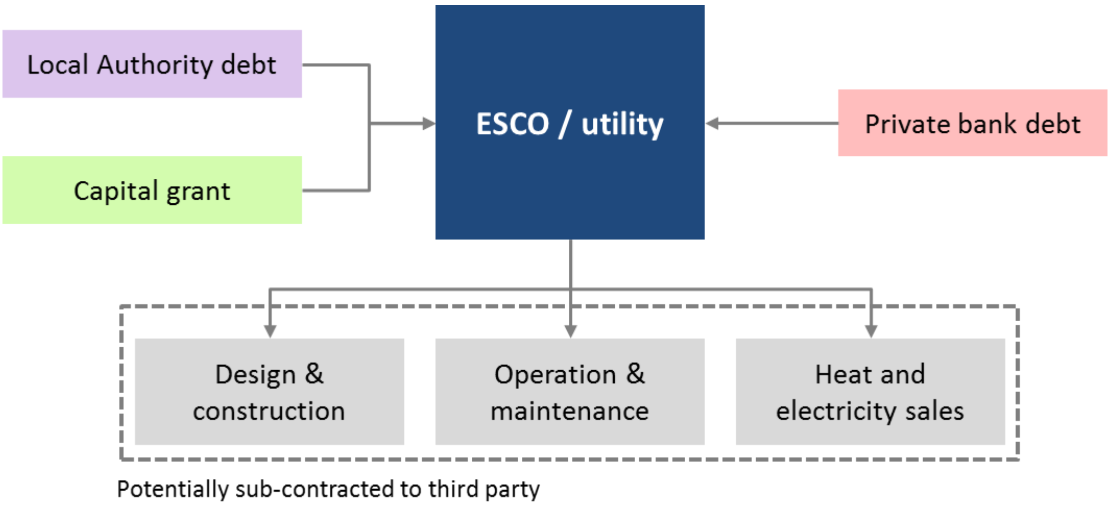

Figure 56: General scheme to illustrate the financing structures which could be used to deliver the heat network

[48] http://www.seai.ie/Grants/Better_Energy_Communities/ (Accessed November 2016)

14 Concluding remarks

Objectives of the energy masterplan

Element Energy were commissioned by South Dublin County Council to develop an energy masterplan for the Clonburris Strategic Development Zone (SDZ) and surrounding areas, including an assessment of a range of low carbon, renewable and decentralised energy opportunities. This report describes the analysis undertaken as part of this work.

This energy masterplan aims to future-proof SDCC's planning and energy policy in light of the potential future impact of national and European legislation such as that described in Section 3. A key objective of this initiative is to continue to develop the evidence base available to SDCC to allow planners, Council staff and other local stakeholders to make more informed policy decisions relating to energy provision in South Dublin. It is also hoped that the work will act as an exemplar for other local authorities to demonstrate the value of the energy masterplanning process, to encourage similar initiatives elsewhere.

The focus of the masterplan is on the various energy provision options available to supply the buildings on this site, including:

- Site-wide and partial **district energy/heat network schemes**;
- **Block-level**/community energy supply;
- **Individual building-level** energy systems.

Energy provision options presented include low carbon and renewable heating and cooling technologies such as air-source, ground-source and water-source **heat pumps**, **biomass** heating and combined heat and power (CHP), **solar thermal**, **gas CHP**, and **solar photovoltaic** renewable electricity generation.

Approach taken in the energy masterplanning process

The following approach has been taken in developing the energy masterplan:

1. Relevant **national and local policy** has been reviewed and the implications for energy provision at Clonburris SDZ highlighted;
2. An **energy mapping** exercise has been undertaken based on the information contained in the emerging preferred scenario, combined with an appropriate benchmarking of new building energy demand;
3. A longlist of **energy provision options** for the site has been developed;
4. **Opportunities for district energy/heat network schemes** covering clusters of high heat demand have been identified;
5. **Initial technical design** of the heat network for each opportunity identified has been carried out;
6. An **economic assessment** of each heat network option has been completed;
7. An **economic and environmental appraisal** of the full range of energy provision options, including heat network, block-level and building-level options has been undertaken, and recommendations made on the most suitable options;
8. The **role of planning policy** in helping the project opportunities identified to be realised has been described;
9. Potential **delivery models** for the project opportunities, and possible **roles for SDCC** in delivering the projects, have been described.

A key aspect of the economic and environmental appraisal of the various energy provision options available for buildings in the SDZ is a consideration from the perspective of the different stakeholders involved, including the end-user, the building developer and the project (e.g. heat network) developer. As such, the appraisal considers the performance of each option in terms of:

- *Internal rate of return (i.e. profitability) to the project developer* (key to ensuring the opportunity is attractive to investors and therefore **deliverable**)
- *Lifetime cost to the end-user* (critical to ensure a **low-cost, secure energy supply** to consumers);
- *Upfront cost to the building developer* (likely to be key to considerations of **economic viability**);
- *CO_2 emissions reduction* (to ensure alignment with local and national carbon **emissions reduction targets**).

Key project opportunities identified

The analysis has identified the opportunity, contingent upon the level of development included in the emerging preferred development scenario, for the development of a heat network at each of the two hubs at Fonthill and Kishoge. Such schemes present the opportunity for low carbon heat to be delivered to end-users at a price that is competitive with the counterfactual gas heating option, with no additional upfront cost incurred by the building developer, and with a heat sale price sufficient to allow the heat network project developer to achieve a commercially attractive rate of return.

A range of delivery models and financing structures could be used to unlock the required investment, as described in Section 13. Whichever delivery model is followed, there will be a critical role for SDCC to influence developers, landlords and tenants to connect to the network, and to use planning policy where possible to encourage connection. The Council may also be a heat customer, ensuring Council-controlled buildings are connected where viable. Alternatively, SDCC could be more directly involved by, for example, providing project finance to the developer, or even participating in a joint venture with an ESCO or consortium to deliver the project.

While, as stated above, the heat network projects identified could be deliverable without additional financial support, the economic case could be improved by – and in the case that the quantum of development at the site is lower than that described in the emerging preferred scenario, may rely on – additional financial support. A range of funding sources could be relevant. A heat network based on a heat pump and/or biomass heating could qualify for the Renewable Heat Incentive (RHI), expected in Ireland in late 2017. Public sector funding from the Council, central government, or through the European Regional Development Fund or similar schemes – in the form of capital funding to reduce the upfront cost to investors, or in the form of low-cost debt finance to improve the rate of return on private sector investment – could improve the economic case and render the project more deliverable.

Value of the energy masterplan to various stakeholders

The energy masterplan is intended to provide value to a range of stakeholders, including SDCC planners, local stakeholders and community groups, and policymakers.

It is hoped that the work illustrates the development of an evidence base relating to the energy provision options against which future planning applications can be assessed, and describes how planning policy could be updated to help realise the opportunities set out in this report. It is also the intention that the work raises awareness among local and community groups, including homeowners, tenants, landlords, landowners and others of the opportunities at Clonburris and the surrounding area to deliver affordable and low carbon energy provision across the area's homes, schools and workplaces. Furthermore, it is the ambition of this work to demonstrate the innovative use of the energy masterplanning process as an exemplar for other developments and local authorities in Ireland. It is hoped that other local authorities will consider undertaking similar exercises to ensure that decisions relating to energy provision for future developments are informed by a robust evidence base aligned with the priorities of local stakeholders, and to ensure a sustainable, affordable and secure energy supply for consumers.

Acronyms

ASHP	Air-source heat pump
CH	Central heating
CHP	Combined heat and power
CODEMA	City of Dublin Energy Management Agency
DHW	Domestic hot water
GSHP	Ground-source heat pump
HIU	Heat Interface Unit
IRR	Internal rate of return
kW	Kilowatt
kWh	Kilowatt-hour
NPV	Net present value
NZEB	Nearly Zero Energy Building
PV	Photovoltaic
RHI	Renewable Heat Incentive
SDCC	South Dublin County Council
SDZ	Strategic Development Zone
SHW	Solar hot water
WSHP	Water-source heat pump

Glossary

Internal rate of return

The internal rate of return (IRR) is a measure of the profitability of an investment. It is the discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. The higher the rate of return, the more profitable the investment.

Kilowatt

A kilowatt (kW) is a unit of power, equal to one thousand watts.

Kilowatt-hour

A kilowatt-hour (kWh) is a unit of energy equivalent to a power consumption of one thousand watts for a period of one hour.

Net present value

The net present value (NPV) is used to assess the profitability of an investment. It is the difference between the present value of cash inflows and the present value of cash outflows. A positive NPV indicates a profitable investment.