South Seeds Renewable Heat Study

A district heating feasibility study of the south side of Glasgow

Report for South Seeds produced by Ricardo Energy & Environment, with support from John Gilbert Architects and British Geological Survey

south seeds
GROWING A GREENER GLASGOW

John Gilbert
ARCHITECTS

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

ED 61460 | Issue Number 1 | Date 02/03/2016

Customer:

South Seeds

Customer reference:

South Seeds Renewable Heat Study

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02 March 2016

Ricardo Energy & Environment reference:

Ref: ED61460- Issue Number 1

Executive summary

Background

South Seeds is a community-led charity that is based in the south of Glasgow. South Seeds main effort goes into helping local residents tackle climate change by taking practical action such as improving home energy efficiency, cutting energy bills and tackling fuel poverty.

South Seeds supported this renewable heat study, led by Ricardo Energy & Environment with input from John Gilbert Architects and the British Geological Survey, to demonstrate the benefits of district heating schemes as a method of tackling the significant levels of fuel poverty in the area whilst reducing carbon emissions. The report provides decision makers with essential information to enable them to make a decision on supporting a detailed feasibility study for a district heating network scheme.

Study area

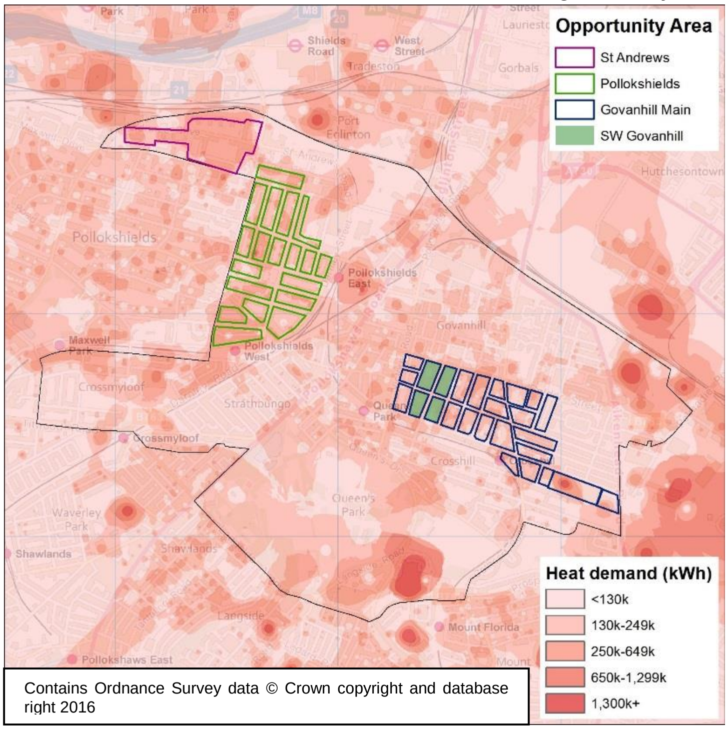
The study areas covers Govanhill, Queen's Park, Crosshill, Strathbungo and Pollokshields East. This comprises 31 data zones defined by the Scottish Index of Multiple Deprivation (SIMD), based on 2012 figures. The Scottish Index of Multiple Deprivation shows that 28 out of the 31 data zones in the study area have housing conditions which are in the bottom 10 per cent of that in Scotland.

This area of Glasgow is densely populated with tenement buildings and hence has one of the largest concentrated space heating demands in Glasgow.

Total heat demand in the area is estimated to be in excess of 980,475MWh. Domestic heat consumption dominates in the South Seeds project area. In Pollokshields, approximately 95% of all heat is for domestic use, and in Govanhill this figure is approximately 85%. In most area wide district heating schemes, anchor loads which have a constant demand for heat form the base load. These anchor loads often consist of large public buildings or commercial heat users around which smaller heat users, such as domestic consumers would be connected. There are few commercial anchor loads in the project area, however the concentration of heat demand from residential properties is significant enough to act as the anchor load.

District heating opportunity areas

Using Scottish Heat Map data, four opportunity areas were identified in the areas of highest heat demand and were defined to minimise crossings of major thoroughfares or physical constraints such as a railway line. Tenement blocks, prevalent in the project area, have between 100 and 200 properties in a block, with a total annual heating requirement in the order of 2,500MWh. These could be connected with a single road district heating network connection, allowing a large number of properties to be easily connected to the network.



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These clusters of tenement properties can be treated as anchor loads in themselves.

These four identified opportunity areas are shown in this diagram:

1. St Andrew's Drive
2. Govanhill Main
3. South West Govanhill
4. Pollokshields East

Economic analysis

Ricardo Energy & Environment used a proprietary district heating economic model to evaluate the economic potential of the identified opportunity areas. The model takes over 100 inputs including indicative energy centre costs, network pipework costs, household infrastructure costs, generation efficiencies and distribution losses to determine the economic viability of each of the district heating options.

Across each of the opportunity areas, a number of different scenarios were evaluated, looking at the cost reduction to householders, thus addressing fuel poverty and the financial return to the owner and operator of the district heating scheme. The key scenario for tackling fuel poverty assumed households connected to the scheme would be billed for their heat at a discount of 20% on the cost of gas to heat households. Heat supplied from a gas combined heat and power system (gas CHP) and heat from the energy from waste plant at Polmadie, the Glasgow Renewables and Recycling Energy Centre (GRREC), were modelled for three of the opportunity areas.

In all three cases using heat from the GRREC was able to offer a positive Internal Rate of Return, a positive Net Present Value at a discount rate of 3.5% and a significant carbon saving as shown in the following table. This indicates a commercially viable and attractive district heating scheme is possible, that would deliver financial savings to households, whilst providing a financial return to the district heating scheme developer.

In all three cases heat from gas CHP was found not to offer a viable business case while offering the 20% saving for consumers.

Heat Source	Pollokshields East	South West Govanhill	Govanhill Main
Total number of connections	2,222	704	3,400
Number of domestic connections	2,082	664	3,154
Total heat demand (MWh/year)	56,905	12,860	63,000
Total Capex (£)	£15.5 million	£4.5 Million	£22.9 million
Total Capacity (MWth)	25.6MWth	5.8MWth	46MWth
Annual operating costs (£)	£742,000	£173,677	£744,360
NPV (£) at 3.5% discount rate	£7.1 million	£884,445	Negative
IRR (%)	8%	5%	3%
Carbon Saved (tCO_2e/year)	10,082	2,355	10,010

Sensitivity analysis of the Govanhill Main opportunity area economic model, adjusting the level of grant funding, savings delivered to heat consumers and the price paid to GRREC for heat, concluded that a district heating network can deliver low cost heating to domestic householders in the area.

The conclusion of this analysis was that heat can be delivered to the 3,400 properties in Govanhill Main, at a price 20% below the cost of heat from a domestic gas boiler, while delivering a payback of under 15 years to the district heating network operator. To enable this, grant funding of between £4.5 million and £9 million is required, depending on the level of financial return offered to the network operator. Without grant funding a network is viable but is not able to deliver heat at as low a cost, which would mean that fewer people were removed from fuel poverty.

The development scenarios for the expansion of district heating were explored and in particular it was demonstrated that the development of the Govanhill Main opportunity area will not only remove a significant number of people from fuel poverty but will allow viable extensions which are more likely to be commercially viable, in particular to the Pollokshields East Opportunity Area.

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1 Introduction

South Seeds is a community-led charity that is based in the south of Glasgow. South Seeds operates across the areas of Govanhill, Crosshill, Queen's Park, Strathbungo and Pollokshields East. Working in partnership with residents and local organisations to help improve the look and feel of the Southside of Glasgow. South Seeds' main effort goes into helping local residents tackle climate change by taking practical action such as improving home energy efficiency, cutting energy bills and tackling fuel poverty.

Improving energy efficiency is the most cost-effective way of cutting energy bills, tackling fuel poverty and reducing climate change impact. Once all opportunities for improving energy efficiency have been taken, the next most cost effective opportunity for reducing the impact on climate change from energy use in the home is to consider how the heat and electricity used in the home are generated.

South Seeds previously completed a study, the Renewables Snapshot[1] which looked at the renewable energy technologies that would be most appropriate for each individual household in the South Seeds project area. This report identified that the heat demand of most domestic properties in the area could technically and economically be delivered by air source heat pumps installed in each property. Building on this study, this Renewable Heat study, led by Ricardo Energy & Environment with support from John Gilbert Architects and the British Geological Survey, evaluates area wide opportunities for district heating schemes that could deliver a cost effective low carbon heating solution that would potentially bring about large scale reductions in fuel poverty in the area.

1.1 South Seeds Renewable Heat Study Overview

This South Seeds Renewable Heat study has been completed to demonstrate the benefits of district heating schemes and to provide decision makers with essential information to determine whether a district heating network in the project area should be explored further via a detailed feasibility study. As this report shows, a district heating network could be a cost effective method of tackling the significant levels of fuel poverty in the project area, whilst reducing carbon emissions.

A heat map of the South Seeds project area was produced to identify the heat demand of the area, identifying significant loads around which it may be suitable to build a heat network. This used data from the Scotland Heat Map produced by the Scottish Government and made available for this study. Additional heat demand estimates were made for the domestic properties using the Standard Assessment Procedure. This heat map is presented in Section 4.

From this heat map, Opportunity Areas were identified for potential district heating networks. These focussed on areas of the highest heat demand density, which coincide with the highest levels of social deprivation as shown in Section 2. The Opportunity Areas are presented in Section 5. Low carbon heating solutions, which include energy from waste, natural gas combined heat and power (CHP), biomass, biomass CHP and extracting heat from mine water were assessed to determine which would be technically feasible to deliver heat to these networks. These are detailed in Section 6.

Once a technical solution for providing heat to the network was identified, a number of scenarios were considered to determine the financial viability of district heating networks that could deliver a 10% and 20% reduction in heating costs for residents in the area. The results of this analysis are presented in Section 7.

This heat study also includes further information on billing arrangements that have been implemented across other district heating networks as this is an important consideration for determining whether a district heating network would work in the project area. Some of the key factors that need to be considered and lessons learned from other schemes are presented in Section 10.

[1] http://southseeds.org/wp-content/uploads/2015/07/Renewables-Snapshot-report.pdf

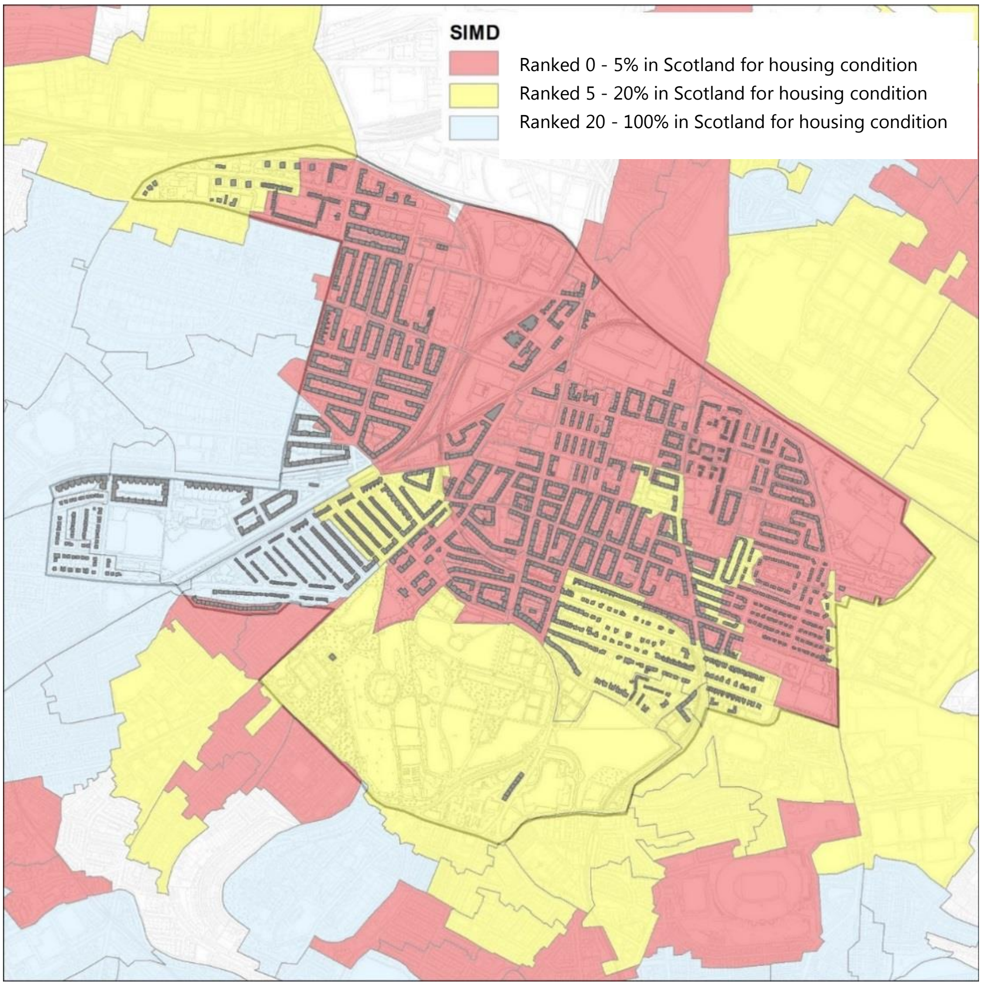
2 South Seeds study area

The unique mix of heat users in the project area will also be reflected in the heat load profile. A wide range of household incomes, mix of ethnic backgrounds and number of householders per property all create a heat demand profile that will differ from other parts of Glasgow. Using heat mapping data together with analysis of the urban form, density and tenure is a useful tool to prioritise and target areas for district heating. This informed which house types are most prevalent within the identified networks and allowed us to consider configurations of mixed tenure in the identification of opportunity areas.

The tenure of ownership presents unique opportunities, with large parts of the area having low levels of private ownership with a high proportion of private and social rented dwellings. Therefore the decision making over the heating solutions being installed in properties when being upgraded is in part driven by the benefits of a low maintenance, centrally managed heating solution.

The study area covers Govanhill, Queen's Park, Crosshill, Strathbungo and Pollokshields East. This comprises 31 data zones defined by the Scottish Index of Multiple Deprivation (SIMD), based on 2012 figures, the most recently available as shown in Figure 1. The SIMD is the Scottish Government's official tool for identifying those places in Scotland suffering from deprivation. It incorporates several different aspects of deprivation, combining them into a single index. The Index provides a relative ranking for each data zone, from 1 (most deprived) to 6,505 (least deprived).

Figure 1: South Seeds project area and Social Index of Multiple Deprivation



The SIMD shows that 28 out of the 31 data zones have housing of such a poor condition that it falls in the bottom 10 per cent of housing across the whole of Scotland. As identified in the South Seeds Energy

Snapshot report[2], the properties which are owned by a social landlord are likely to be of a higher energy efficiency rating than those of private landlords. There are currently requirements for social landlords to ensure that their properties meet prescribed energy efficiency ratings, the Energy Efficiency Standard in Social Housing (EESSH), however no such requirements exist for private landlords. The Scottish Government is still reviewing the impact that district heating schemes will have on the quality of housing scores, but it is expected to be positive. The Scottish Government has a target of 40,000 homes to be connected to district heating schemes by 2020, with 11% of all heat to come from renewables, so district heating in the project area would support these goals.

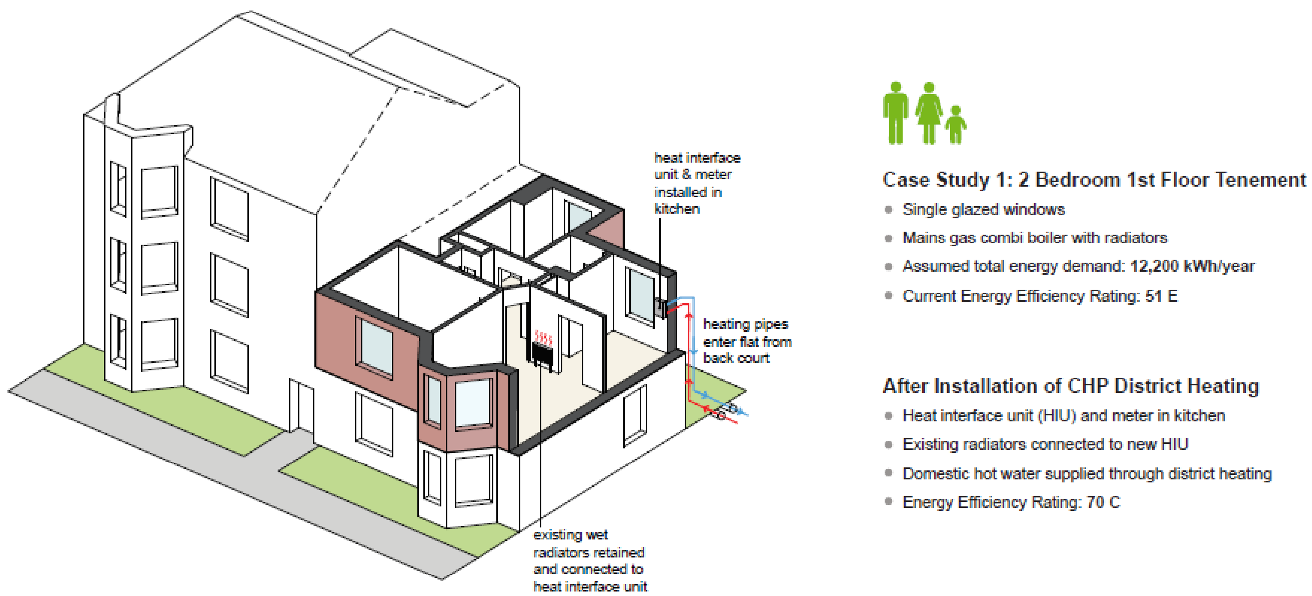
2.1 Housing types

This area of Glasgow is densely populated with tenement buildings and hence has one of the largest concentrated space heating demands in the city. Four tenement flat types were selected to provide an overview of the typical properties within the project area, Short Tenements, Standard Tenements, Dense Tenements and Retail Tenements in line with the definitions from the South Seeds Energy Snapshot report.

2.1.1 Short tenements

The Short Tenements were constructed in the inter-war period of the 1920's and 30's. This type of tenement typically has smaller windows and lower ceiling heights than Victorian or Georgian tenements resulting in a smaller space to heat. However the walls are poorly insulated, similar to other tenement buildings.

Figure 2: Short tenement layout (diagram by John Gilberts Architect)



A typical flat is occupied by a small family, with annual space heating and hot water costs in the region of £1,000 a year to provide an average level of thermal comfort (section 8.1.2 details how this was calculated). There are a number of factors that will influence these costs, including ability to pay.

Figure 2 illustrates the modifications that would need to be made to a tenement property to connect it to a district heating scheme, with the addition of an internal Heat Interface Unit (HIU) in the back kitchen, with a connected meter and pipework running externally to the property. Section 7 includes more detail on what these modifications look like.

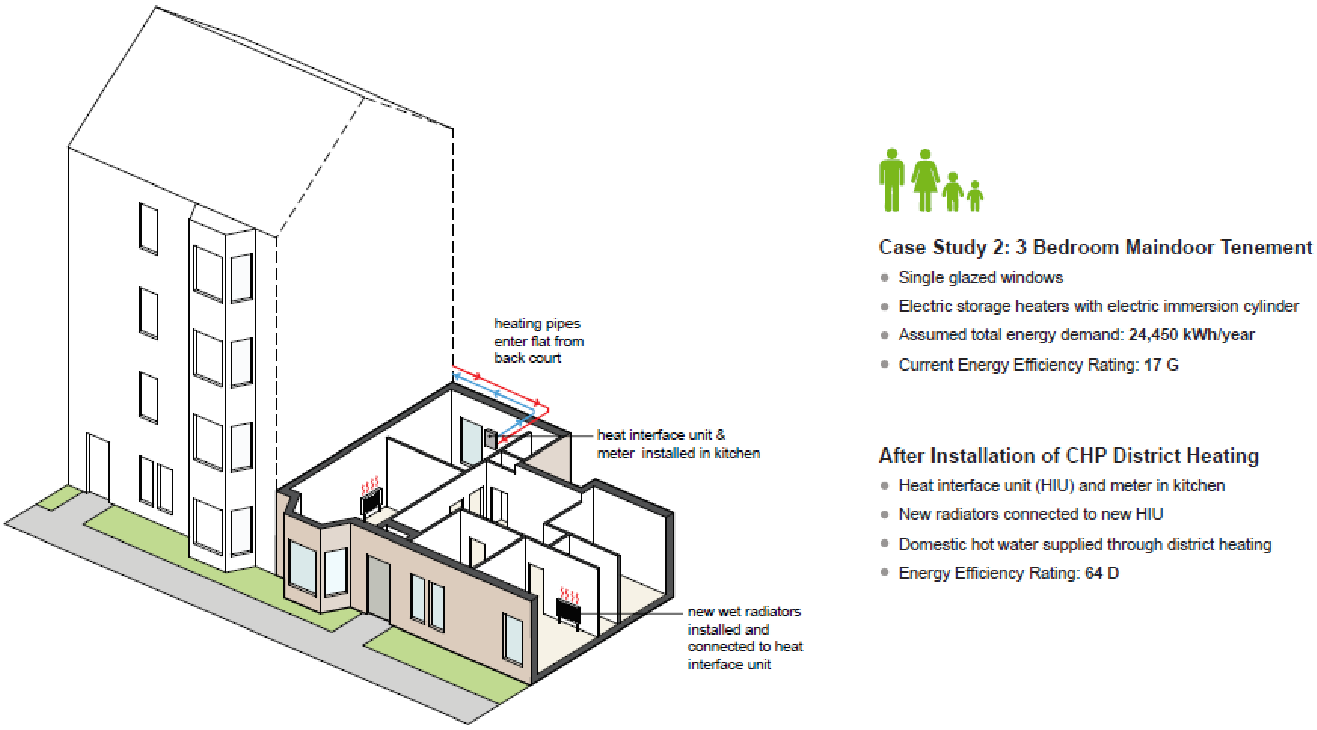
[2] http://southseeds.org/wp-content/uploads/2013/04/Energy-Snapshot-Report.pdf

2.1.2 Standard tenements

The Standard Tenement is usually symmetrical and repetitive, though there will be exceptions at corners and unusually shaped blocks. The flats are generally among the largest of the tenements, with large windows and a small front garden space.

A standard tenement in the Govanhill Main area, occupied by a larger family, might find the annual heating and hot water costs closer to £1,800 a year. South Seeds have reported that there are a significant number of tenement flats in the area that have a higher occupancy than this, which will significantly influence these costs. Higher occupancy within a flat can reduce some heating demands when all occupants are in the building, however it is more probable that there will be people present during the day. Hot water and space heating demand will therefore increase with increased occupancy, so costs will increase.

Figure 3: Standard tenement layout (diagram by John Gilberts Architect)

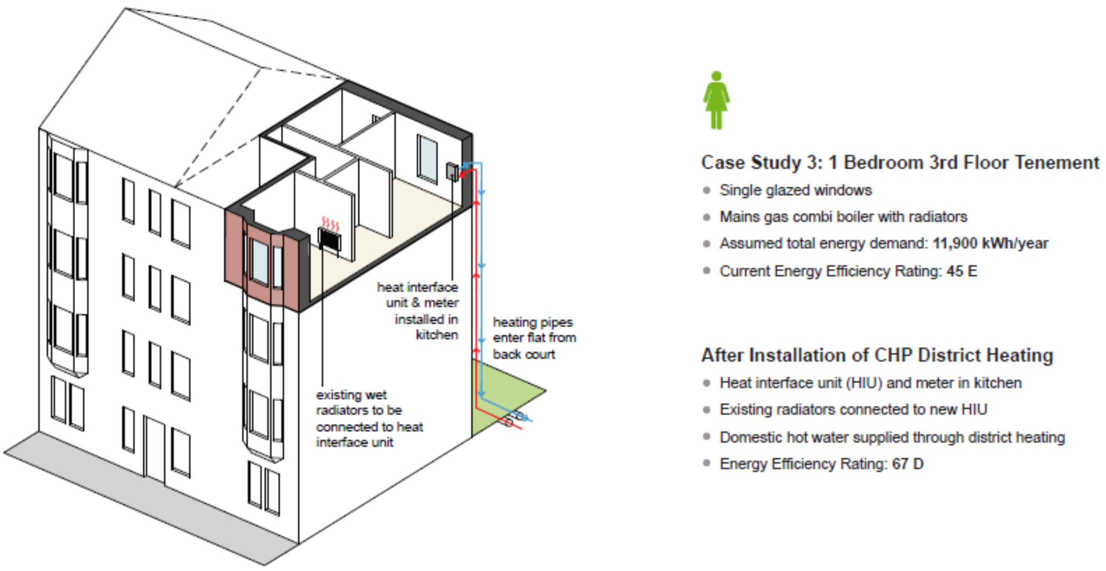


For those properties that do not currently have a wet heating system there will be more upheaval and cost associated with connecting, but if there is no current wet heating system, the savings from switching from electric to district heating will be even more significant than from gas heating. This is detailed further in Section 7.

2.1.3 Dense tenements

These blocks of tenements are densely packed with smaller flat sizes. The windows are medium sized with a high proportion of glazing to solid wall, hence greater heat losses. A key difference from the Standard Tenement is that the ground floor does not have a small front garden as a buffer to the street.

Figure 4: Dense tenement layout (diagram by John Gilberts Architect)

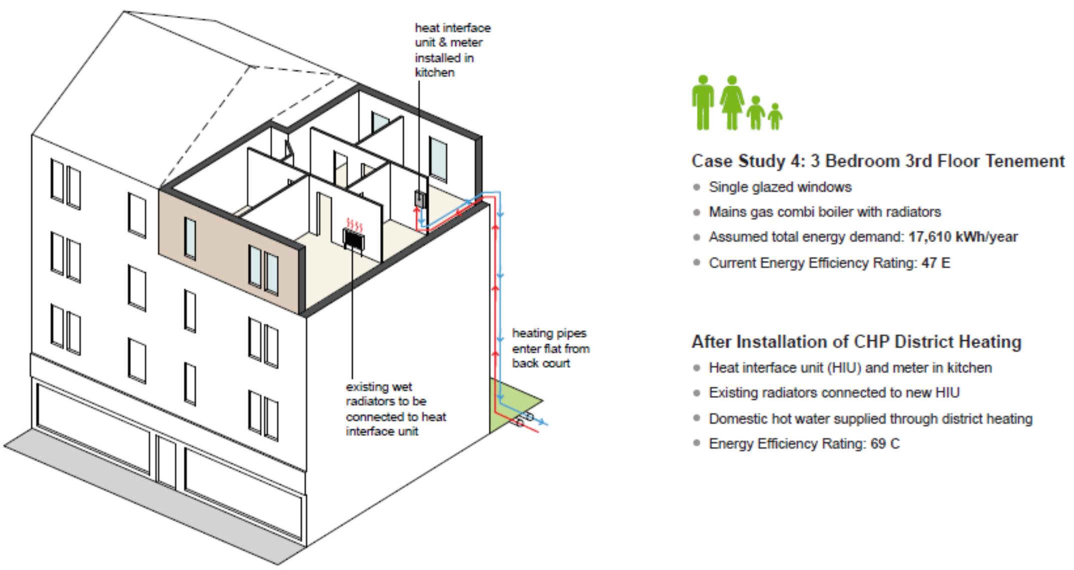


As these are smaller single or dual occupancy properties, heating and hot water demands are less at approximately £900/ year. The diagram shows the minimal impact a district heating scheme would have on the fabric of the building.

2.1.4 Retail tenements

The Retail Tenements are similar in scale to the Short Tenements, but with a retail or commercial space on the ground floor. The windows are small to medium in size so heat losses are reduced, and the flats are located on main streets with no front gardens.

Figure 5: Retail tenement layout (diagram by John Gilberts Architect)



Typical heat costs for a small family might be in the region of £1,400 a year. Again Figure 5 shows the minimal impact that connecting to a district heating scheme might have on the fabric of the building.

3 District heating schemes

3.1 Characteristics of district heating

It is usual in the UK for properties to be heated by their own heat source, for example a gas boiler. However it is possible and increasingly more common, to heat a large number of properties using a single heating system. The properties are connected by insulated pipework and are supplied by one or more large centralised heat sources in a district heating scheme.

Whilst district heating schemes are common place in Scandinavian countries, they are becoming more common in Scotland:

- **West Whitlawburn:** Over 540 high rise and low rise properties in Whitlawburn in Cambuslang, as part of a partnership between West Whitlawburn Housing Co-operative (WWHC) and npower, are heated by a district heating scheme with heat supplied by biomass boilers with £6.5 million funded by Energy Company Obligation funding, Scottish Government Warm Home Fund loan funding and European Regional Development grant funding.
- **Wyndford Estate:** More than 1,500 properties in the Wyndford Estate, Maryhill are supplied by a district heating scheme heated by a 1.2MW Gas CHP engine and gas boiler backup as part of a development for Cube housing association supported by £2million of Scottish Government funding.
- **St Andrews Drive:** Southside Housing Association are investigating a biomass district heating scheme in their new build properties planned for St Andrews Drive in the south of Glasgow. (See Section 5.1.1)

The Scottish Government "Energy in Scotland 2016" report shows over 100 district heating schemes planned or in operation across Scotland[3].

On the continent there are examples of district heating schemes that use heat stored in water collected in abandoned mines to provide low cost, low carbon heat such as the scheme in Heerlens, the Netherlands. Approximately 3,500 people receive their heating from water that was pumped into mines abandoned in 1976. The water is geothermally heated and pumped to homes, shops, a conference centre and a café.

District heating schemes form an important part of the Scottish Government Heat Policy with a target of 40,000 homes benefiting from district heating by 2020, and 1.5TWh of heat delivered to domestic and non-domestic properties by district heating by the same date[4].

A district heating scheme is operated by an organisation that is responsible for:

- Operating the system;
- Arranging maintenance; and
- Billing of heat consumers.

This operator of the scheme is often a separate organisation owned by a local authority, housing association or private company usually on a joint venture basis between several parties. The day to day responsibility for operation, maintenance and ensuring continuity of heat supply is often contracted out to a company experienced in the technologies being used on behalf of the operator.

3.2 Benefits of district heating

A district heating scheme can deliver heat at a cheaper price than domestic boilers for a number of reasons:

- Larger heating systems can make more cost-effective use of low carbon heat sources or those which deliver heat at a lower price than domestic boilers, for example gas CHP, energy from waste or industrial scale biomass boilers.
- Operators of large systems can purchase fuel at a lower price than domestic consumers.

[3] http://www.gov.scot/Resource/0049/00493362.pdf
[4] http://www.gov.scot/Publications/2015/06/6679

- A district heating scheme would typically heat hundreds or thousands of properties. These properties will need heat at slightly different times. The more constant the heat demand on the system the cheaper the heat will be.

For a tenant, the additional benefits of a district heating scheme are:

- Lower cost of heat;
- The tenant retains full control over heat demand;
- Health and safety advantages from not having gas appliances in the home.

Owner occupiers will experience the same benefits as well as reduced operating and maintenance costs. There is only one central heat supply requiring maintenance, with the maintenance of the heat network managed by the operator of the scheme. Also, since the cost of maintenance is covered in the cost of heat this means that there are no one-off maintenance bills, such as boiler servicing.

For housing associations and other landlords there are additional benefits:

- The cost of heat for their tenants is lower;
- There is no need for natural gas boilers and the associated risks and costs of installation (gas may still be required for cooking unless fully replaced by electricity);
- The carbon footprint of the heat is typically lower than boilers, contributing to carbon targets;
- District heating will improve the energy efficiency of the property, thus contributing to EESSH targets. This can be seen in the energy ratings in Figures 2, 3, 4 and 5.

3.3 Tackling fuel poverty

The overarching goal of South Seeds is to support those residents in its project area who are struggling to deal with fuel poverty, whilst reducing carbon emissions in the area. An appropriately designed and funded district heating scheme can support this aim.

In this feasibility study we looked at a number of different potential Opportunity Areas, within the South Seeds project boundary. This includes areas within Pollokshields and across Govanhill and Queens Park, which we describe in more detail in Section 5. A number of different technology solutions were considered including combined heat and power, energy from the mine workings under the project area and heat from the energy from waste plant at Polmadie, the Glasgow Recycling and Renewable Energy Centre (GRREC). Each of these are outlined in Section 6.

From these we identified a scenario for the Govanhill Main Opportunity Area in which a district heating scheme, using heat from the GRREC, would be financially attractive to a district heating scheme operator. In this scenario the heat was charged to consumers at a 20% reduction on the existing cost of heat, based on average gas central heating costs, thus addressing the significant problems with fuel poverty in the area. It should be noted that it is estimated that 11% of properties in Glasgow are on electric heating, in which cases, savings could be even greater[5]. To enable such a scheme to be economically viable does require significant grant funding, which would require further investigation into the impacts of State Aid.

Full details of the scenarios considered are shown in Section 6.

[5] Scottish Housing Condition Survey

4 Heat demand in South Seeds area

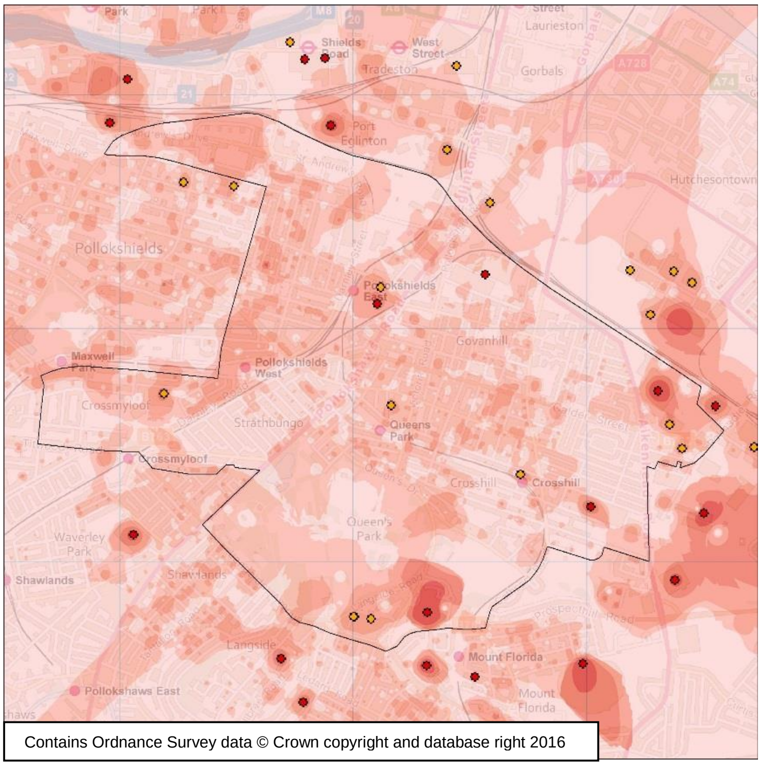
Total heat demand in the area is estimated to be in excess of 980,475MWh. Domestic heat consumption dominates in the South Seeds project area. In Pollokshields, approximately 95% of all heat is for domestic use, and in Govanhill this figure is approximately 85%. In most district heating schemes, anchor loads which have a constant demand for heat form the base load. These anchor loads often consist of large public buildings or commercial heat users around which smaller heat users, such as domestic consumers would be connected.

4.1 Anchor loads

Across an area extending 500 meters beyond the study area potential anchor loads were identified using data from the Scottish Heat Map (see Section 8.1).

Figure 6 shows a heat map of the area, with Hampden Park and Cathkin Park visible for reference. The darker the area, the greater the heat demand in that area. The sites with a usage of over 1,300MWh per year have a red marker and those of more than 650MWh per year are shown with an orange marker. These thresholds were determined to align with potential sources of heat from combined heat and power plants or biomass plants (see Section 6).

Figure 6: Large heat loads (>1,300MWh red dots; >650MWh orange dots) within South Seeds project area



It is clear from the map that there are very few commercial anchor loads in the project area that are also close to areas of high heat demand. Those in the north west of the study area, located next to Albert Drive, are bounded by railway lines which can be a constraint to running district heating pipes. In the south of the study area there is Victoria Hospital and a number of commercial properties which are closer to GRREC but only have a small number of domestic properties nearby, so may not be suitable anchor loads for a district heating network. Holyrood School in the centre of the study area is an ideal candidate as an anchor load, as is St. Bride's Primary School which has a swimming pool. The consistent areas of relatively high heat demand are situated across tenement block areas.

A block of tenements consists of between 100 and 200 properties, with a total annual heating requirement in the order of 2,500MWh. These could be supplied from a single road connection from a district heating network which would heat all of the properties via a local branch network to the rear of the properties. These clusters of tenement properties can be treated as anchor loads in themselves.

4.2 Identifying opportunity areas

Blocks of tenement flats were identified that could be connected without crossing any major thoroughfare or railway line. The exception to this, shown in Figure 14 is the pipeline running from GRREC to the project area, which has to cross Aitkenhead Road to bring heat to the area. There are three main areas of the study area where this is the case: Govanhill Main, Pollokshields East and St. Andrews Drive.

The Pollokshields East Opportunity area is bounded mainly by the physical constraint of the railway. It would be possible to extend the network to Hutcheson's Grammar School to the south or to integrate the St Andrews drive area to the north. However these were not included in the analysis in order to maximise the heat density captured and minimise the network length.

The Govanhill Main area has no such physical constraints. The network decided upon was that which was judged to be most likely to be technically viable. The Holyrood Secondary School to the east of the opportunity area provides an anchor load between the tenement properties and the Govanhill Main opportunity area (see figure 7). This area was designed to minimise the distribution network required while maximising the number of property connections and heat density. It would be possible for the network to be extended to the west or to the north and any future analysis should not only consider the phasing of the network proposed but also the possibility of enlarging it.

The St. Andrew's Drive opportunity area is bounded to the north by the railway line and the south and east by main roads Maxwell Drive and Shields Road. Across both these roads, the heat density drops significantly.

A further area was also identified in South-West Govanhill, (see figure 7) where there are tenement flats with a particularly large heat density. Since these are the subject of a focused renovation plan by Govanhill Housing Association, they have been included as a separate opportunity area.

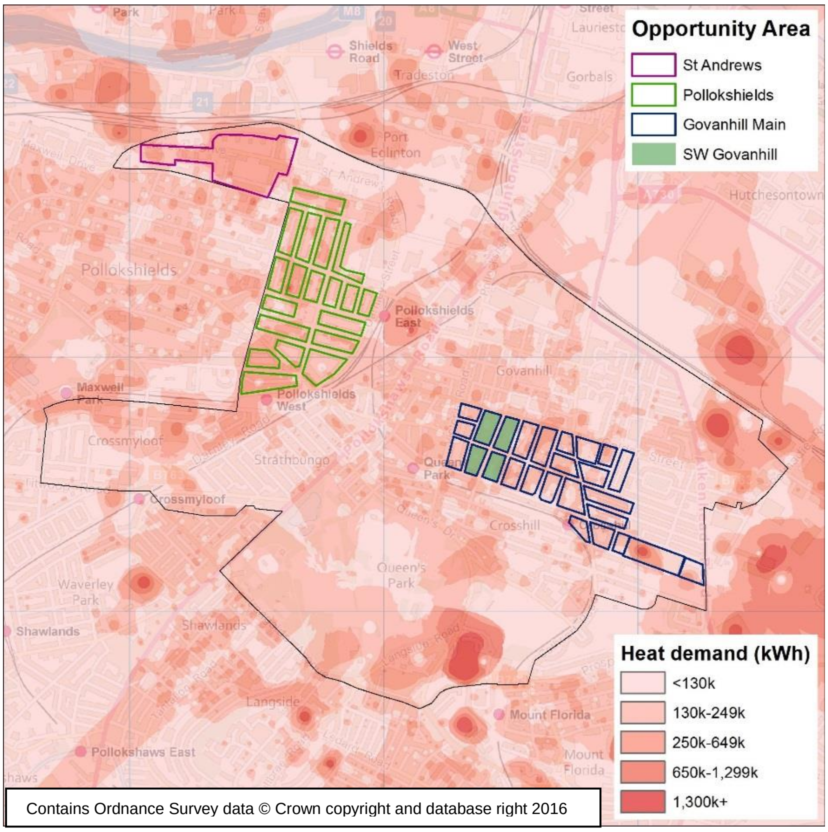
5 District heating opportunity areas

The heat map in Figure 7 shows the heat demand from the Scottish Heat Map. The four areas identified are also shown. These Opportunity Areas are located in the areas of highest heat demand. With no suitable non-domestic heat loads identified to act as an anchor load, the concentration of domestic heat demand is used as the anchor loads.

These four identified areas, shown in Figure 7, are:

1. St Andrew's Drive (extended);
2. Govanhill Main;
3. South West Govanhill (part of Govanhill main;
4. Pollokshields East.

Figure 7: South Seeds Opportunity Areas



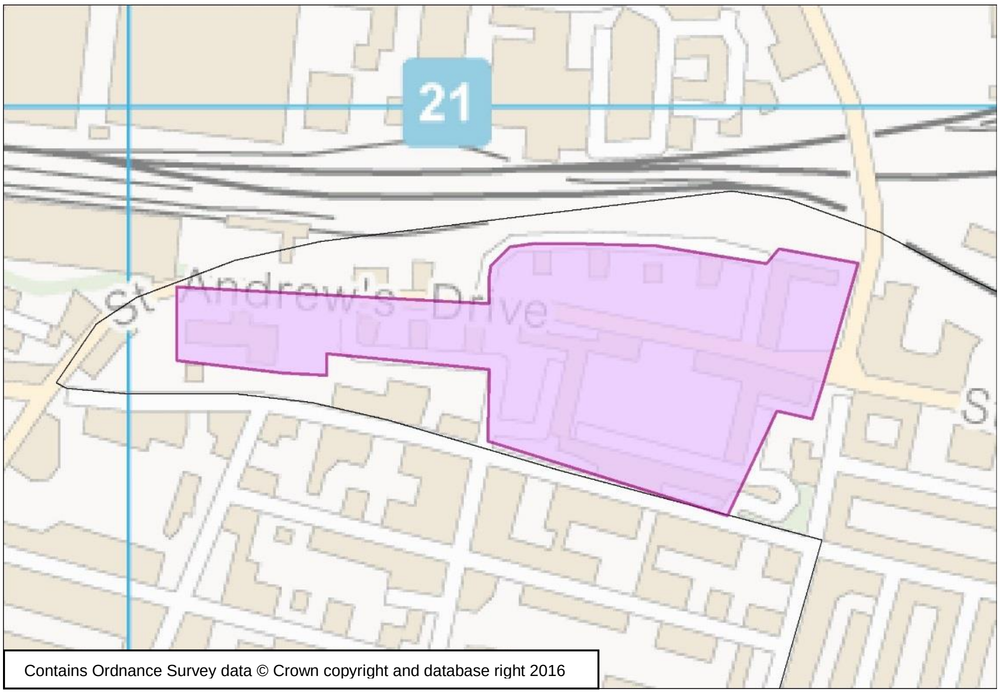
5.1 St Andrew's Drive (extended) Opportunity Area

This constitutes an area to the west of Shields Road, and to the south of the railway line that runs east-west, itself south of the M8 between the M74 and M7. At the time the heat data used in the heat map was generated, the area was made up of 7, 8-storey apartment towers, seven large blocks of apartments (6-storeys), and two refurbished 6-storey blocks of apartments.

This area is undergoing significant renovation. A majority of the housing in the area is owned by Southside Housing Association, a registered social landlord, which is undertaking a major re-build program. It was confirmed that the seven large blocks of apartments were in the process of demolition, to be replaced with a new development. Plans for the new development were not provided to Ricardo Energy & Environment to consider in its assessment.

The apartment towers also appeared to have been relatively recently refurbished and it is understood that plans for a district heating scheme in the area are currently being considered. Hence, this area was not considered further in this assessment.

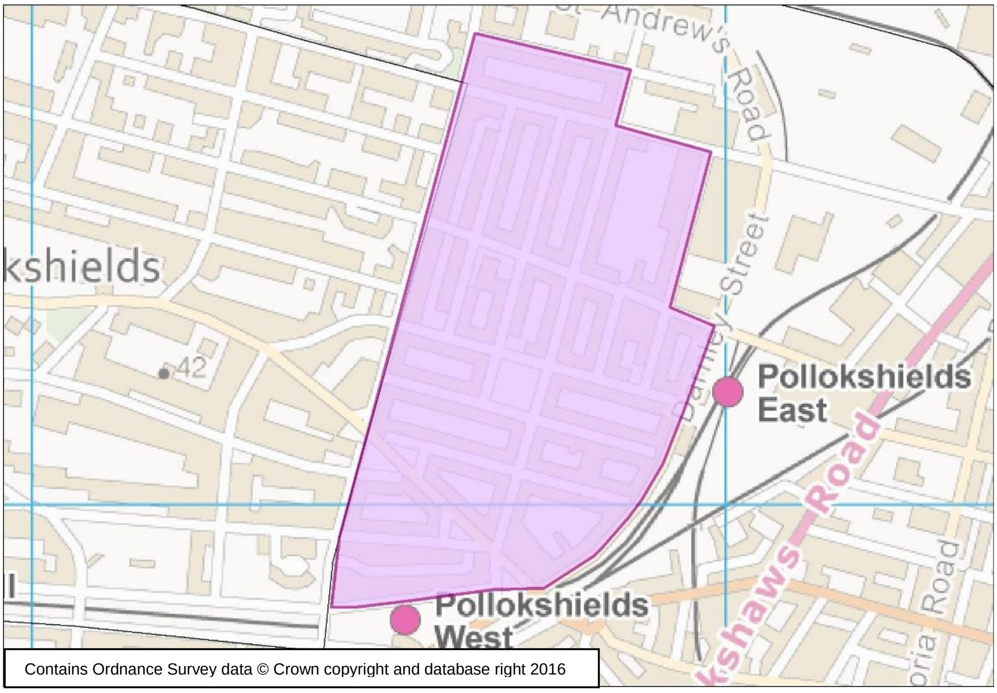
Figure 8: St Andrew's Drive OA



5.2 Pollokshields East Opportunity Area

This area lies to the north and west of Darnley Street, and to the east of Shields Road. The study area was drawn around 19 property blocks of interest, all being broadly tenement type blocks as shown in Figure 9. This area is at the boundary of South Seeds project area to the west, which is also the boundary to the area of highest heat demand density. To the east the railway line forms a boundary. Crossing railway lines with a district heating network is possible, but will be more expensive and disruptive than crossing a road. Almost all the housing types in the project area are those described in Section 2.

Figure 9: Pollokshields East OA



Heat demand is still relatively high to the south of this opportunity area and this is a potential area for expansion towards Hutcheson Grammar School. The number of connections points, types of connection and total heat demand are shown in Table 1.

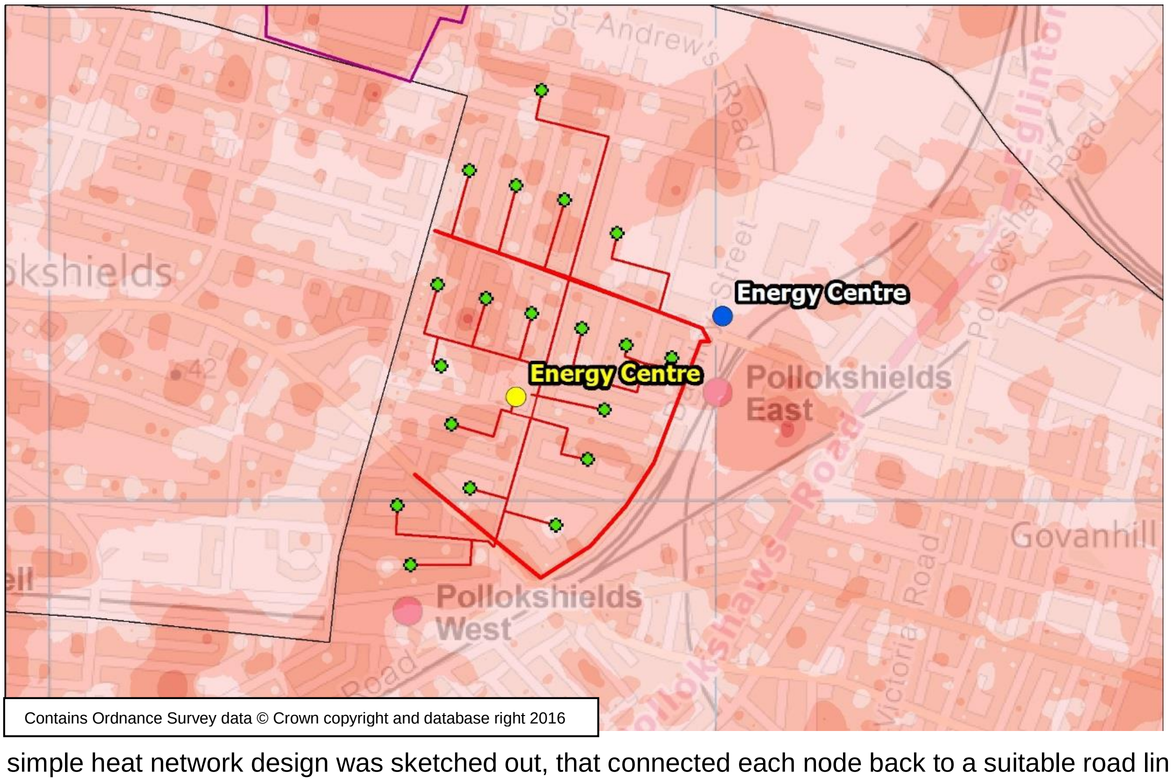
Table 1: Pollokshields East OA Connections

Designation	Number of connections	Heat demand (MWh/yr.)
Total	2,222	56,905
Residential	2,082	54,294
Churches/community centres	4	396
Schools	2	791
Other Non-Residential	134	1,424

5.2.1 Distribution infrastructure

Each block is approximately square in fashion, and it is straightforward to consider the supply of a heat network to a node, or heat substation, roughly central to the internal areas of the block, from where connections could be made to each flat. Each node would consist of a manifold and pumping equipment which would pump heat to the 10 to 15 tenement buildings surrounding the node. This could be located either in a small building or in a manhole chamber underground. The network pipes and nodes are shown in Figure 10.

Figure 10: Pollokshields East Opportunity Area distribution network.



A simple heat network design was sketched out, that connected each node back to a suitable road line and subsequently back to an assumed location of the area energy centre, where the heat source(s) would be located. From this sketch the length of required pipework was determined. For the Pollokshields East Opportunity Area, the total length of this transmission network is 3.26km, consisting of pipework of 300mm diameter, although a detailed study would determine the exact pipe diameter. Using benchmark figures for district heating systems the estimated cost for such a network is £2.2 million, which is explored in further detail in Section 7.

5.2.2 Energy centre

The heat supply for this network would come from a new energy centre installed within the Opportunity Area. There are a number of potential sites for this as indicated in Figure 10, such as the current open space located on the corner of Melville Street and Kenmure Street or on the corner of Albert Drive and Darnley Street. Further detailed analysis would identify the optimal location for the energy centre. Figure 11 is an artist’s impression of what an energy centre here would look like. Further detailed analysis would be required to identify a specific location.

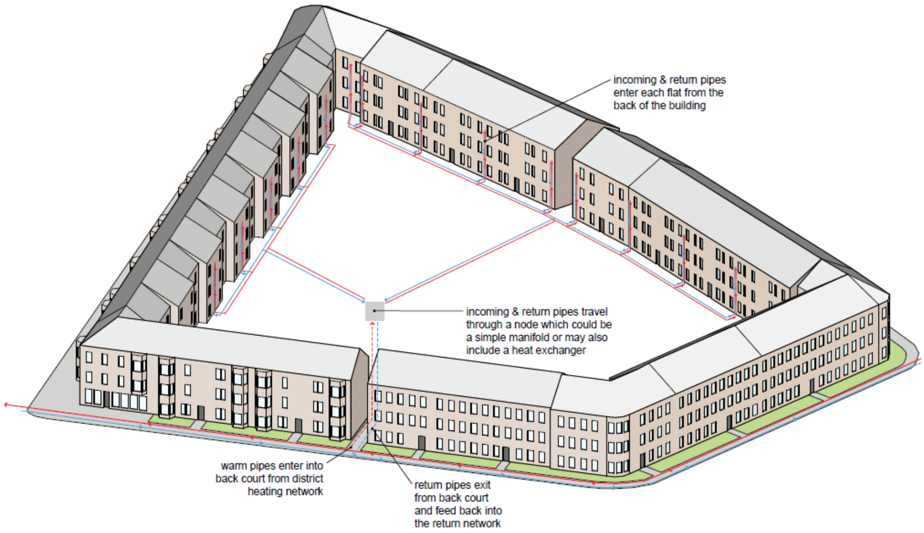
Figure 11: Potential Pollokshields East Energy Centre (drawing by John Gilberts Architects)

Section 6 has further information on the different types of heat source considered for the opportunity area. For such a large scale opportunity area, the conventional source of heat would come from a Combined Heat and Power plant (CHP) that generates both heat and electricity. For this opportunity centre, a CHP plant, with gas fired back up/auxiliary boilers was calculated to have electrical capacity of some 16.1MWe and a thermal output rating of 53.5MWth. The estimated cost for such an energy centre is £16.2 million, which is explored in further detail in Section 7.

5.2.3 Local infrastructure

The heat is transferred from the energy centre, through the distribution network to the heat substation or node in each back court of the properties. This node would typically serve a total of 100 to 200 flats as shown in Figure 12.

Figure 12: Heat distribution network connecting to nodes in each back court (diagram by John Gilberts Architects)



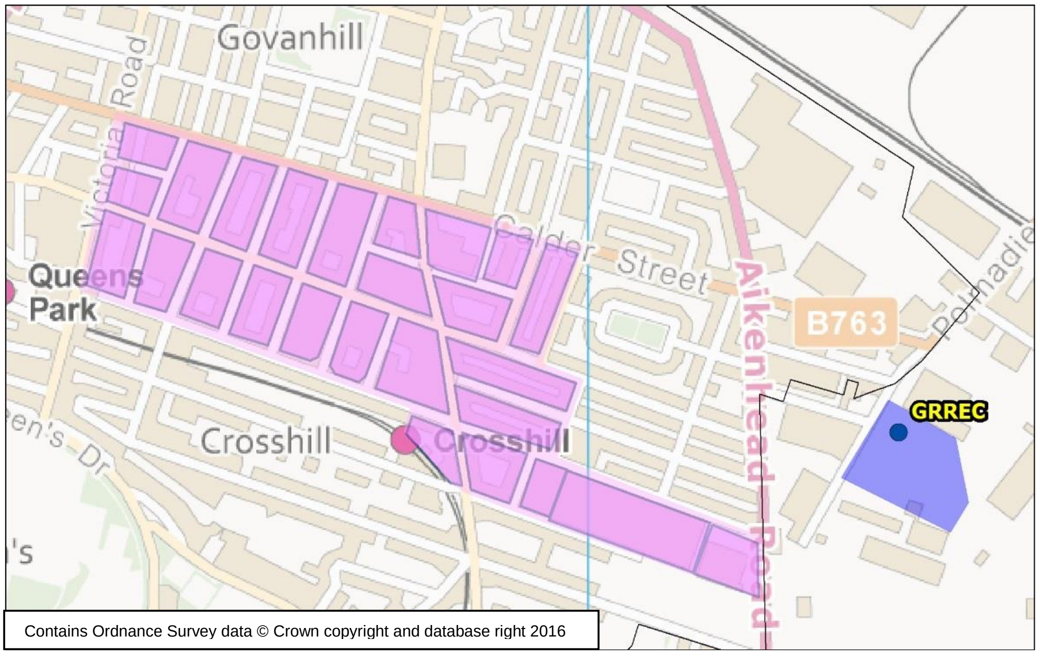
Within each property will be appropriate heat exchanger units, such as Heat HIUs that replace an existing fired boiler, and all necessary metering equipment to allow for the monitoring and billing of the heat consumed (further information on this is included in Section 10). The estimated cost for this element of the network is £10 million.

The same approach has been used to identify other opportunity areas in the South Seeds project area, with the Govanhill Main Opportunity Area being another suitable area for the district heating network.

5.3 Govanhill Main Opportunity Area

This area lies to the south of Calder Street and to the east of Victoria Road. The eastern edge stretches to the Holyrood Secondary School and the Holyrood Sports Centre, down to Aitkenhead Road. The Southern edge is Dixon Avenue and down to Albert Road east of Cathcart Road. The Govanhill Main Opportunity Area (GMOA) is dissected by the A728 Cathcart Road as shown in Figure 13.

Figure 13: Govanhill Main Opportunity Area



The area was identified as it is bounded by main roads and crossing main roads can be more expensive and disruptive. Beyond these boundaries the heat demand drops to the south and east. The density of the heat demand within the South Seeds project area is greatest within the boundaries of this opportunity area as the domestic properties are most densely packed. To the north and west, the heat density remains high. These would be the likely areas to extend the heat network to with future development.

The number of connections points, types of connection and total heat demand are shown in Table 2.

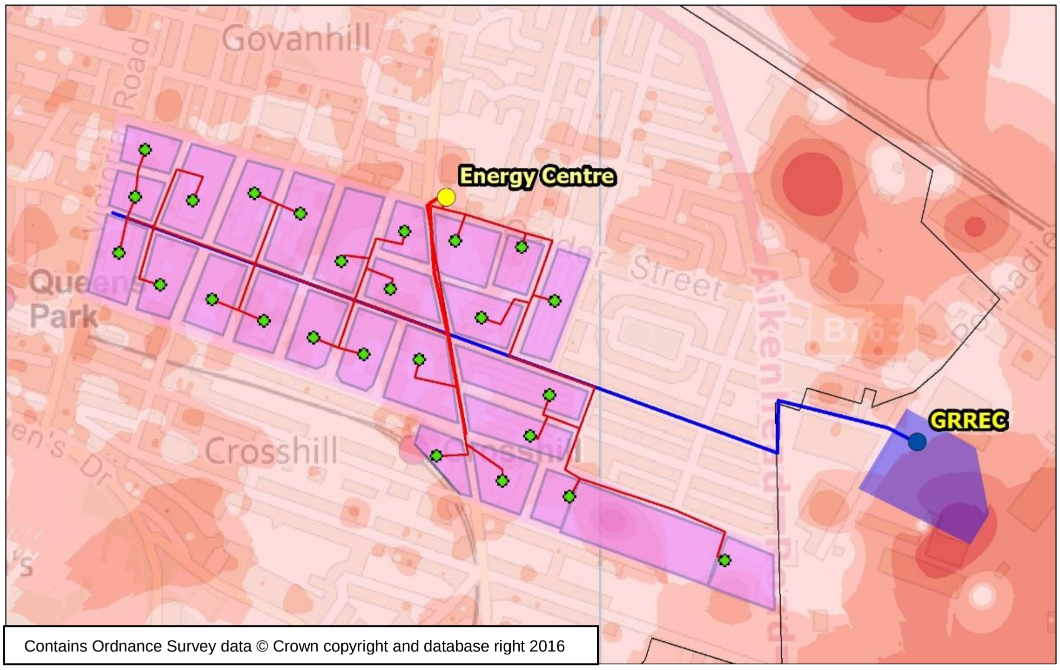
Table 2: Govanhill Main Opportunity Area Connections

Designation	Number of connections	Heat demand (MWh/yr.)
Total	3,400	63,000
Residential	3,154	56,676
Churches/community centres	13	1,472
Schools	6	3,154
Other Non-Residential	218	1,900

5.3.1 Distribution infrastructure

The distribution network of pipes and nodes is shown in Figure 14. For GMOA, the total length of this required transmission network is 3.6km of pipework 300mm in diameter. The estimated cost for such a network is £3.7 million.

Figure 14: Govanhill Main Opportunity Area distribution network.



5.3.2 Energy centre

For the GMOA, one potential location for an energy centre is the area of unused land located adjacent to 'The Gym', on the north side of Calder Street, at the junction with Cathcart Road. Again detailed analysis is required to determine the optimal location for the energy centre which would be influenced by the appropriate heat source used to provide heat to the network.

An energy centre for the GMOA, which utilises gas CHP technology, with gas fired back up/auxiliary boilers was calculated to have an electrical capacity of some 30.3MWe and a thermal output rating of some 101MWth. The estimated cost for such an energy centre is £30.4 million.

If heat from GRREC is used for the district heating scheme and it were to stop generating then it would be important to ensure continuity of heat supply. This backup generation could be located at the nodes, a separate energy centre or at the GRREC plant itself. This would need to be considered at detailed design stage.

5.3.3 Local infrastructure

The local infrastructure for this opportunity area from the distribution node to individual properties, with HIUs and all necessary metering equipment has been estimated to cost £15.6 million.

The final opportunity area identified is a subset of properties that sits within the GMOA.

5.4 South-West Govanhill Opportunity Area

Figure 15: South-West Govanhill OA

The South-West Govanhill Opportunity Area (SWGOA) is a group of tenement properties that are currently being targeted for redevelopment as part of a £9 million regeneration program in the area where Govanhill Housing Association have recently purchased 60 properties. This Opportunity Area comprises of four blocks, located within the boundary of the GMOA, between Calder Street in the north and Dixon Avenue in the south, and Westmoreland Street in the west and Annette Street in the east.

The numbers of connections and total heat demand identified are shown in Table 3.

Table 3: South-West Govanhill OA Connections

Designation	Number of connections	Heat demand (MWh/yr.)
Total	704	12,860
Residential	664	12,481
Churches/community centres	1	2
Schools	0	0
Other Non-Residential	39	312

5.4.1 Distribution infrastructure

For SWGOA, the total length of the required transmission network is 640m. As the heat demand from this Opportunity Area is significantly lower than the other areas, the required pipe size is much less with an average diameter of 125mm. A detailed feasibility study would confirm this. The estimated cost for such a network is £0.36 million.

5.4.2 Energy centre and local infrastructure

For the SWGOA, one potential location for the energy centre is located on the area of land located in the south west corner of the OA, adjacent to 83 Westmoreland Street. In comparison with the other Opportunity Areas, if utilising gas CHP, the electrical capacity of the plant is considerably smaller, as you would expect for such a small area, at 5MWe and a thermal output rating of some 17MWth. The estimated cost for such an energy centre is in the region of £5 million.

The estimated cost for the local infrastructure, including the pipes from the nodes to the properties, the HIUs and the meters is £3.1 million.

The cost of each of the energy centres in the different Opportunity Areas is significantly influenced by the appropriate heat technology for that area which is discussed in the next section.

6 District heating technologies

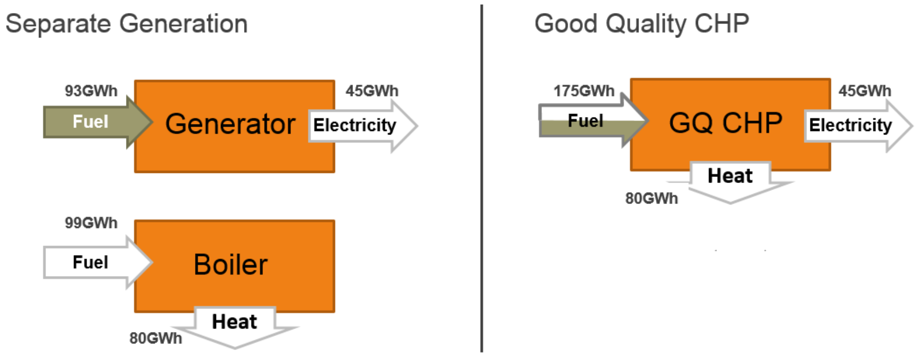
In the UK, gas CHP is the most common technology used for district heating schemes. The Glasgow Recycling and Renewable Energy Centre, which is due to commence operation at Polmadie in 2016, will generate significant quantities of heat once operational. As it is so close to the South Seeds project area this is another heat source that has been considered. The study area, as with most of central Scotland, is underlain by coal seams of various depths which have been extensively mined. These mines are no longer in use and are believed to be flooded, thus holding large quantities of heat which has been used to provide heat to other district heating schemes in Scotland. Finally, biomass is another low carbon source of heat which is considered here.

For each of the technologies an assessment was made of their technical viability to provide heat to each of the opportunity areas identified.

6.1 Gas combined heat and power

CHP plants can lead to significant fuel, cost and emissions savings over conventional, separate forms of power generation and heat-only boilers. Capital costs are higher than conventional generators however, due to their higher combined efficiency (i.e. electrical and thermal efficiencies), CHP plants outperform their generator and boiler counterparts. As illustrated in Figure 16, CHP plants can provide the same heat and power output as a generator and a boiler, but with a lesser fuel input requirement.

Figure 16: Separate generation vs. CHP for similar heat and electricity outputs



For large capacity plants, natural gas is the most common fuel for reciprocating engine CHPs in the UK. This can be explained by the fact that gas prices are lower, performance is higher, maintenance is less demanding and emissions are cleaner (when compared to diesel and petrol engines). CHP is often sized to meet a site's base load (heat) and sized such that it operates at full load all year round. Boilers may provide remaining heat required to meet the site's total demand. Consequently, the electrical efficiency is maximized, along with the CHP's combined efficiency (accounting for the fact that electricity is a higher grade of energy than heat).

Sites with high heat base loads that extend throughout the year are therefore those that can gain the most from CHP technologies. District heating networks which supply a diverse range of heat loads at different times of year are a prime example. In addition to this, the use of CHP technologies (as opposed to separate generation) is encouraged in the UK: the government has introduced a number of fiscal and financial support mechanisms, which can be cumulated with further incentives in the case of renewable fuels.

As gas is easily available in the project area, the main constraints are identifying a suitable location for the energy centre in which to house the plant, which would be the focus of a detailed feasibility study. From a technical perspective, gas CHP would be a suitable technology to provide heat to all opportunity areas. An example energy centre containing a gas CHP plant is shown in Figure 17.

Figure 17: Gas CHP Energy Centre providing heat to approximately 2,000 flats

6.2 Energy from waste

The Glasgow Recycling and Renewable Energy Centre (GRREC) being constructed by Viridor will process waste from green (general waste) bins in Glasgow. The site will remove any recyclable waste to boost recycling. Organic waste will be treated in an Anaerobic Digestion (AD) process to generate biogas. This biogas will supply CHP engines which will supply electricity to the National Grid and will recover heat that can be delivered into a heat network. Finally, waste that cannot be recycled will be passed to an advanced conversion facility to generate energy. This system converts the energy in the waste into steam which powers a steam turbine to generate electricity. Some of the steam can be extracted from the steam turbine to deliver heat into a heat network.

A requirement of the Pollution, Prevention and Control permit is that the site is required to achieve certification from the Combined Heat and Power Quality Assurance (CHPQA scheme) within 7 years[6]. CHP plants certified by CHPQA can receive financial benefits and incentives. This will require the site to ensure that the heat which is generated is put to use, so a viable use for heat from the plant must be identified.

The main hurdle to be overcome with supplying heat to properties from GRREC is the formation of a heat network required to distribute the heat and the constraints on deploying a wide network of pipes under roads and into domestic properties.

By using the arrangement of nodes shown in Figure 10, Figure 12 and Figure 14 the number of pipes running under main roads can be minimised. This has a significant advantage in reducing the time and therefore cost of the main distribution network. The connection between individual properties within buildings and buildings to nodes can then be programmed and costed for either individually as required.

There are no insurmountable constraints in the area that would prevent a district heating scheme from being deployed. Constraints that there are in the area such as the layout of other utilities (electricity,

[6] Paragraph 2.7.4 of http://www.sepa.org.uk/regulations/consultations/public-participation-under-ppc/ppds-hidden/1110002/

gas, broadband) can be managed, but may add additional cost. This would become apparent with a more detailed feasibility study.

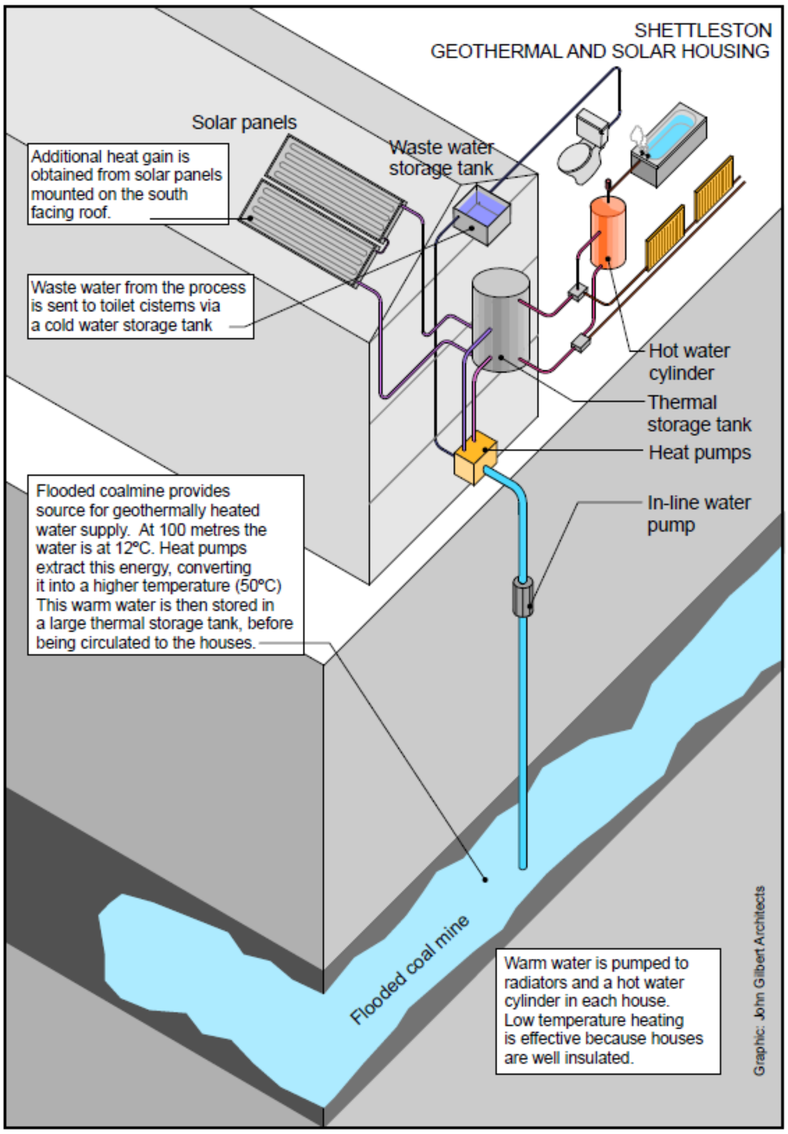
One mechanism for recovering the capital cost of installing such a network is in charges for the heat being provided to heat users. It will therefore be important to maximise the amount of heat which is used by any district heating scheme to reduce the cost to each heat user of repaying the capital cost of the infrastructure. As such it will be important to ensure that a sufficient number of heat users will sign up to purchase heat. This would require widespread engagement within the community in addition to signing up owners of multiple properties in the area, such as housing associations and private landlords.

In Section 7, we detail some other scenarios for funding that would deliver a financially viable scheme, but technically there are no barriers to GRREC providing heat to all Opportunity Areas.

6.3 Mine workings

Glasgow is underlain in many parts by a network of abandoned mines at a variety of depths. The coal mines existed as a network of shafts and roadways that led to the coal seams from which coal was extracted. Most of the seams were allowed to collapse after the coal had been extracted. The void spaces created in these collapsed layers can still store and transmit significant volumes of groundwater.

Figure 18: Geothermal heating from mine water in Shettleston (diagram by John Gilberts Architect)



The mine workings exist over a range of depths. The water temperature varies quite significantly between these depths because the Earth's temperature increases with depth (geothermal gradient). More energy can be extracted from warmer water so deeper mines are most likely to be useful for geothermal energy.

The heat from the water in the mines can be extracted via a heat pump to provide domestic heating. A district heating scheme in Glenalmond Street, Shettleston in the East of Glasgow is heated by a heat pump system which uses water from mines. Figure 18 shows how the scheme in Shettleston operates, with the heat from the mines charging a single thermal store, which then feeds into each separate property.

British Geological Survey (BGS) conducted an initial assessment of the heat resources available from mine water beneath the project area[7].

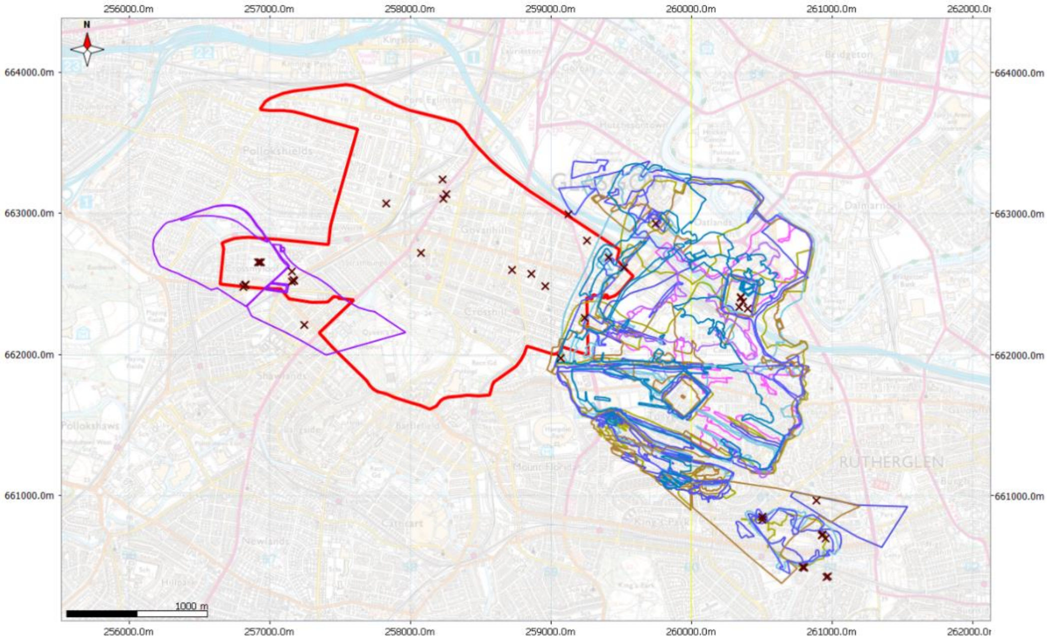
As part of its Clyde Urban Super Project (CUSP), BGS has developed detailed 3D geological models of the layers of rock beneath Glasgow and adjoining

[7] http://southseeds.org/category/resources/

areas. Further information on the coal seams under the project area were added to these models. These were used to estimate total volume of groundwater contained in the mine workings, the temperature of the groundwater and the amount of heat recovery available from them.

There are a number of mine workings which are known to exist directly underneath the project area but could not be evaluated for heat extraction due to lack of sufficient information on either their locations or their depths. This is a key barrier to the development of the mine workings as a potential source of heat. Due to the age of the mines, there are limited records available on their location.

Figure 19: Outline of all 3D modelled surfaces, and positions of shafts (black crosses).



This shows that there are extensive mine workings known to exist at various depths to the east of the study area, which is outlined in red. Each coloured outline represents a coal seam which has been mined, each colour representing a different seam at a different depth. These are the seams where there are sufficient records about depth and condition. There is a smaller mine working very close to the surface to the south west of the study area. Glasgow City Council state that this has been infilled with cement. This has happened across a number of the mine workings in the area.

It has been estimated that it might be possible to extract 1.76MW of heat for geothermal purposes from the deeper levels of the mine workings, from the groundwater which would be at 14°C. This would be enough to heat approximately 200 households if it could be commercially extracted.

There is still uncertainty about the amount of heat available for extraction. To remove this uncertainty the following is recommended:

- Mine locations and condition; further expensive exploratory work to determine the state of the mine, involving drilling and probing;
- Mine characteristics; improving knowledge of the mine workings and the 3D model in terms of depth, thickness, location of significant structures through additional data analysis;
- Fluid characteristics; improve knowledge of possible pumping rates from the mines and temperature of mine water through measurements; and
- Model the sustainability of a geothermal mine system through building a numerical fluid flow model, which would also require system specifications such as desired locations of boreholes and flow rates.

However, these reasons why it is unlikely be viable are specific to the study area. This does not suggest that this technology will be unviable in other areas of Central Scotland, where the former mine workings are better documented.

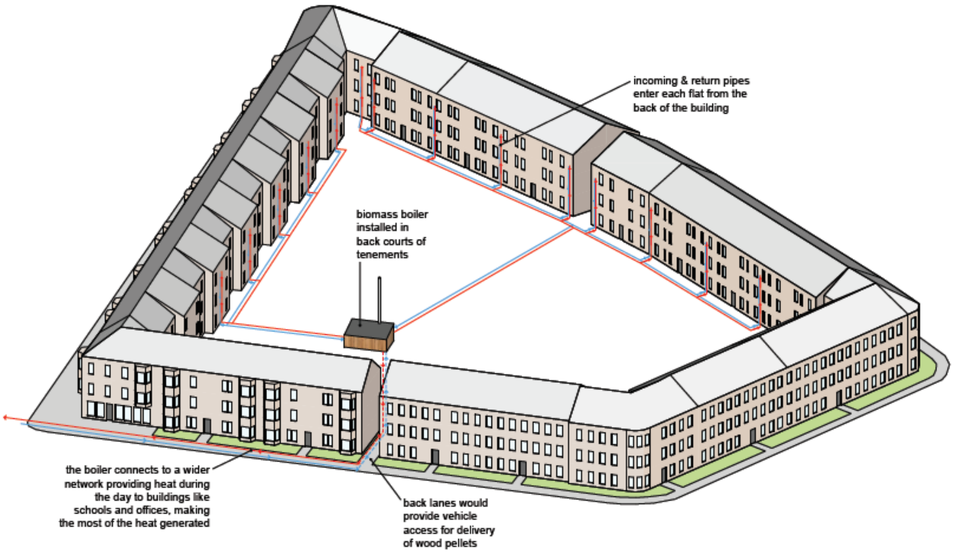
6.4 Biomass boilers

There are a number of case studies of biomass boilers being used to provide low carbon heat to district heating schemes, such as West Whitlawburn in Cambuslang. They are considered low carbon because the carbon dioxide which is released by burning the fuel is absorbed by the fuel being grown to replace it. Provided the fuel crop is replaced after it is harvested, the fuel itself is carbon neutral with only fuel transport and handling adding a small carbon footprint, 0.0128kg/kWh for wood chip compared to Natural gas is 0.184kg/kWh[8].

There are many biomass fuels available. The commonly used ones include:

- Virgin wood fuels (wood pellets or wood chip);
- Energy crops (miscanthus or willow); and
- Waste wood.

Figure 20: Biomass boiler serving surrounding properties (diagram by John Gilberts Architect)



Biomass boilers are eligible for the Renewable Heat Incentive provided they meet the eligibility criteria, which includes sourcing the fuel from sustainable sources. The biggest challenges in locating a biomass boiler in the study area which is capable of heating a district heating scheme are:

- Air quality issues;
- Space required, including for fuel storage and handling; and
- Access for fuel deliveries.

6.4.1 Air quality

Although biomass boilers releases significantly less CO_2 than fossil fuels, there are some pollutants that biomass systems emit in greater quantities than natural gas which affect local air quality. There are ways in which flue gases can be treated to abate these pollutants, which add to the costs of a system but may be required for planning permission or environmental permits. Ceramic filters or electrostatic precipitators can be used to reduce particulate emissions for example.

6.4.2 Space required

Biomass systems take up more space than fossil fuel systems as they require significantly larger fuel stores and fuel handling equipment. This makes finding a suitable location more challenging. They also require good transport links as biomass fuel has to be transported by road.

[8] DECC carbon factors 2015

6.4.3 Fuel deliveries

An example of the fuel consumed by a 3MWth wood chip biomass boiler is shown in Table 4. This is for illustrative purposes only to shows the likely number of deliveries. The actual system output and fuel consumption will depend upon the detailed design factors which are not considered here. On average, this equates to 1.2 deliveries per day of 40m^3 using a 3-axle tipper lorry. As this would require access through the tight streets of Govanhill, it is unlikely that a larger vehicle could access the site.

Table 4: 3MW biomass boiler fuel consumption

Boiler capacity	**3,000**	**kW_{th}**
Assumed Load factor	50%	
Heat generated	13,140,000	kWh/year
Efficiency	85%	
Energy input from fuel[9]	15,458,823	kWh/year
Number of tonnes of fuel	4,417	tonnes/ year
Number of deliveries	442	Per year
Number of deliveries	1.2	Per day

The assumption in this calculation is that the heat demand is consistent throughout the year, when in reality it would peak during the winter. Wood pellets are an alternative, more expensive, higher energy content fuel that could be used, so would require fewer deliveries, but still one delivery per day on average from a 3 axle bulk delivery lorry. This means biomass is unlikely to be a suitable source of heat for any of the Opportunity Areas identified.

6.5 Biomass CHP

The technologies used for gas CHP are not all suitable for use with biomass directly as reciprocating engines or gas turbines are not suitable to burn solid fuels. However biomass fuels can be gasified and the gas burned in either of these technologies. Alternatively a biomass boiler can be used to raise steam which can be used by a steam turbine or the biomass can be burned in a steam engine. Gasification involves heating the biomass fuel to around 700°C with a controlled amount of oxygen to produce a synthetic gas. This gas is then burned in a gas CHP system. In the same way as the fuel supplies for a biomass boiler restrict its viability as a potential solution, this applies to biomass CHP schemes. This is shown in Table 5.

An example biomass CHP system suitable for the South West Govanhill Opportunity Area, would generate 0.6MW of electricity and approximately 3MW of heat using a boiler and an Organic Rankine Cycle engine. This would deliver 13,140MWh of heat. This would equate to 2.1 deliveries per day from a 3 axle articulated lorry, so again this would not be a viable solution.

Table 5: 3MW biomass CHP plant fuel consumption

Boiler capacity	**3,000**	**kW_{th}**
Assumed Load factor	50%	
Heat generated	13,140,000	kWh/year
Efficiency	50%	
Energy input from fuel[9]	26,280,000	kWh/year
Number of tonnes of fuel	5,475	tonnes/ year
Number of deliveries	750	Per year
Number of deliveries	2.1	Per day

As a result of this constraints analysis of the different technologies, gas CHP and heat from GRREC remain as suitable technologies that could be used to provide heat to all Opportunity Areas.

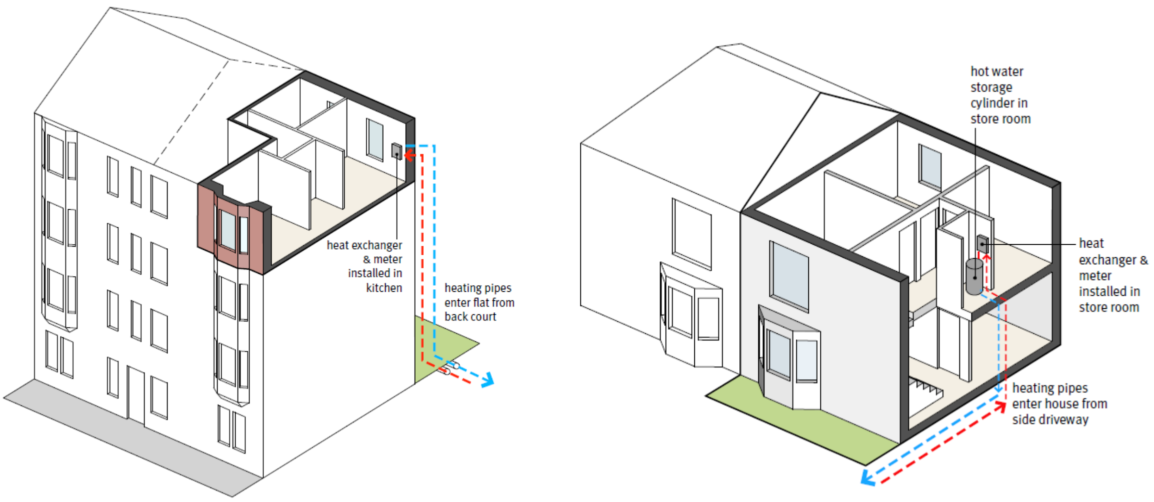
[9] Assumed woodchip used as fuel supply with energy content at 3,500kWh/tonne

7 District heating infrastructure

For those properties that already have a wet heating system, there are a minimal number of modifications that are required to supply the properties with hot water from a district heating scheme which we discuss in the following section. For those properties that do not currently have a wet heating system, the upgrades internally to the property will be very similar to that of installing a gas central heating scheme.

Every property will have an HIU which transfers heat from the network to the house. No bigger than a domestic boiler, this would sit in its place and the house holder would feel no difference in the heat delivered. Hot water can either be provided instantaneously, as in a combi-boiler or using a hot water storage tank as shown in Figure 21.

Figure 21: internal modifications to domestic properties (diagram by John Gilberts Architect)



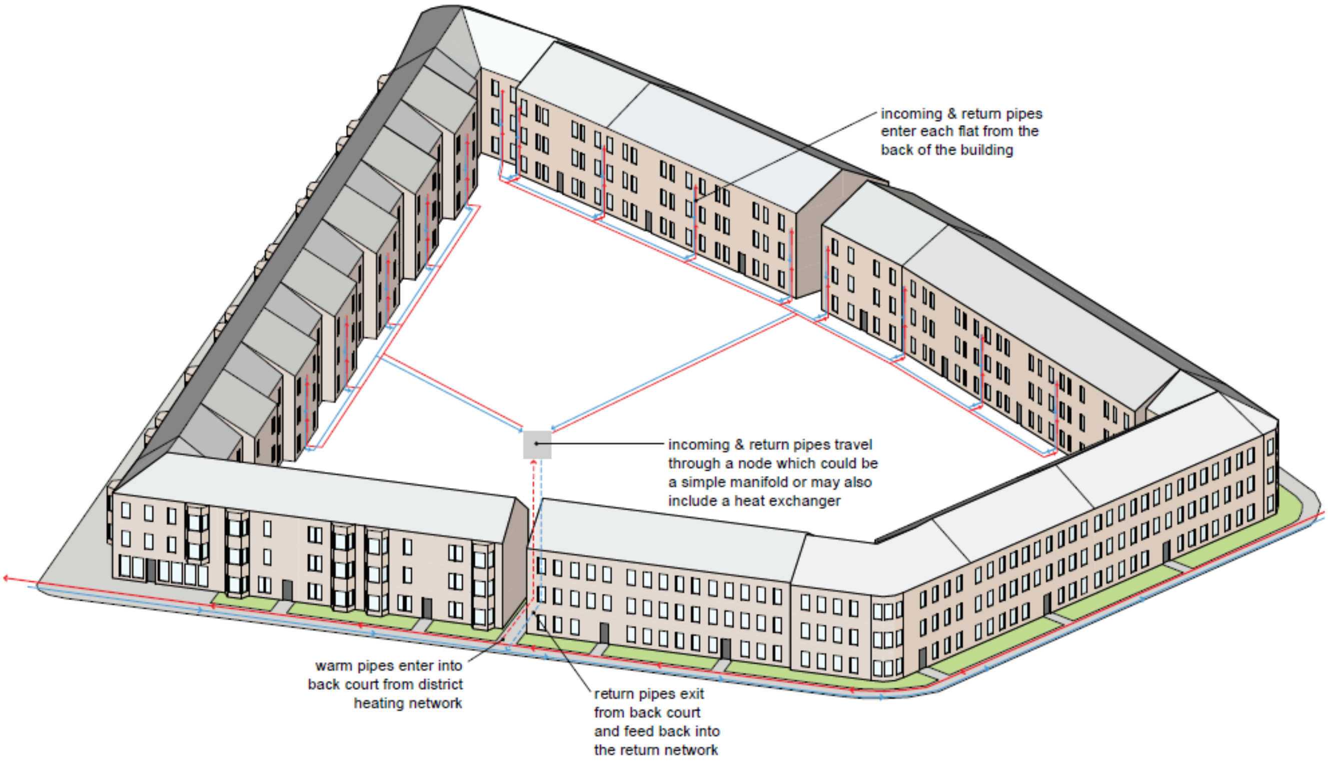
The HIU would be installed in each property is smaller than a combi-boiler, with few moving parts, so very little maintenance is required. The cost of the HIU is included in the cost of the heat network. It is assumed that a wet heating system is present. The cost to the householder would be made competitive to incentivise connecting to the scheme.

In a tenement property district heating pipework could run up the rear and would look similar to drainage pipework visible on most buildings as shown in Figure 22. Insulated pipework would run along main roads, with a single point of entry to the close to the node connected in the back court.

Figure 22: District heating distribution and transmission pipework

All of the flats in a block are connected to a single pipework system as shown in Figure 23.

Figure 23: District heating pipework layout (diagram by John Gilberts Architect)



For the identified Opportunity Areas, it is likely pumping stations would be located at intervals along the network. The size and location of these pumping stations would be determined during detailed design of the scheme. Each pumping station is likely to be no greater in size than a telephone box and would be located at a suitable location on the street.

The district heating infrastructure, would cross common parts of a tenement and use shared space in the back court. To support the development of district heating schemes, the Scottish Government is currently consulting on the regulations that would prescribe services for which an owner of a flat is entitled to lead pipes, cables or other equipment through common parts of a tenement. The service being prescribed is heating services, which relates to the installation of pipes for district heating and communal heating. The regulations also set out the procedure for exercising those rights[10].

For the Opportunity Areas identified, an indicative district heating network was designed which details all the required infrastructure. From this, the next step is to determine whether they could be made economically viable.

[10] http://www.gov.scot/Publications/2016/01/3668

8 Economic analysis

Ricardo Energy & Environment used a proprietary district heating economic model to evaluate the economic potential of the identified opportunity areas. The model takes over 100 inputs including the number of connections, the length of pipework, the discount rate, the cost of fuel, boiler efficiencies and cost of tenement heating system upgrades to determine the economic viability of the project. A list of assumptions is included in Appendix A.

This is presented as Internal Rate of Return under a number of different scenarios including different sources of finance, such as grant funding or debt funding and different heat prices to the properties connected to the scheme. The scenarios detailed below show the investment returns for the project based on varying heat prices comparable with gas central heating up to a 20% reduction in heat prices, with a view to providing cheaper low carbon heat to those in the opportunity area.

The model provides an early stage indication of the financial viability of a district heating project. It is not an investment grade finance model. A more detailed economic assessment should be completed as part of the detailed feasibility study.

8.1 Heat map data

Scottish Government have produced a heat map[11] which provides building resolution heat data for the total annual heating consumption of domestic and commercial properties as shown in Figure 7. A number of sources were used to produce the map, predominantly estimates based on floor area, with a large amount of the data coming from building energy performance data. Inherently there are uncertainties with data from these sources, so a sense check was also carried out of all large heat loads and outliers and anomalies (such as electrical substations) were excluded.

This data was used to determine the opportunity areas detailed in Section 5. To increase the accuracy of the data, SAP assessments were completed for the different property types in the study area. The largest of these heat loads was used as a cap for domestic heat loads. This ensured any erroneously high loads were excluded and provided a robust data set suitable for this pre-feasibility assessment. The next step in building an investment case, during a detailed feasibility study, would revisit the data on a street by street basis to increase the accuracy of the heat data.

8.1.1 Aggregated domestic loads

Given the heat demand density in the identified opportunity areas, the nodes detailed in Figure 10 and Figure 14 form anchor loads in themselves with sufficient heat demand to justify a network connection to that node.

While the total amount of heat used by each group of properties is known, the distribution of the heat usage is not known i.e. the daily and monthly demand profile. It is anticipated that these properties will have different requirements for heat. The heat usage profile of these aggregated loads will need to be modelled as part of a more detailed analysis, using say gas distribution data for the study area to determine how the heat consumption of a large number of domestic properties in the study area, is spread throughout the day. This would be an essential to preparing a more detailed business case.

8.1.2 SAP data

Standard Assessment Procedure (SAP) is used to assess a dwelling's energy efficiency and environmental impact. SAP ratings are banded by letters from A to G with corresponding efficiency ranges within the banding. A higher number reflects a better SAP rating within a band, with A being the most efficient banding. SAP will calculate an expected space heating and hot water demand, which can be used to estimate the annual running costs of the property. SAP calculations are used to produce an Energy Performance Certificate.

The Scottish Building Standards require a SAP calculation to be carried out to demonstrate compliance with energy performance requirements. SAP calculations are also required to demonstrate energy performance in sustainable benchmarks such as The Energy Efficient Standard for Social Housing (EESSH). The Scottish Government have introduced EESSH to ensure all social housing meets a

[11] http://www.gov.scot/heatmap

certain standard by 2020. District heating schemes are one way in which these social housing standards can be met. A low carbon district heating scheme has a positive impact on the SAP ratings of a property, so provides one solution for social landlords to meeting the EESSH.

8.2 Economic model

An economic model was generated which determines a cash flow for the heat network for a lifetime of up to 40 years, using 2016 as the base year. The model calculates the capital cost for the heat network and the energy centre; the operating costs of energy to fuel the network; the operating costs of the network and the sales of heat. The following summarises how this is calculated.

8.2.1 Heat loads

Heat demands for each block (node) are determined from the heat map data. This lists all connections which can be spatially analysed to determine which ones are in the same block. Non-residential connections are separated from the residential connections, based on the property class within the data.

There are two key parameters required in designing a heat network. One is annual total heat demand, the other is peak heat demand. These are used to determine the capacity of the heat technology required.

For residential loads:

- The average heat demand per connection is calculated across all nodes in MWh per year.
- The number of connections is taken from the heat map data for the opportunity area.
- The average was multiplied by the number of connections in all nodes to arrive at the total heat used in the network.
- The peak load for the network was determined using an assumed peak heating load of 10kW per connection.

For non-residential loads:

- Each non-domestic heat load was allocated to a building usage type such as office, light industrial, school etc.
- The total annual demand (in kWh) in each sector was calculated at each node
- The peak load was determined by dividing the total demand by an assumed number of full load operational hours for that sector.

8.2.2 Residential gas price

It was assumed that all properties being treated are currently being heated by natural gas. This is a conservative assumption as natural gas is a cheaper source of heat than electricity. Figures on the amount of properties heated by electricity are not available for the area (although estimated to be 20.9% across the whole of Glasgow[12]). Residential gas prices used were from the Department of Energy and Climate Change projections being 5.11p/kWh in 2016 and a residential gas boiler efficiency of 91%. This resulted in a cost of heat for residential properties, using a domestic gas boiler, of 5.61p/kWh. The actual boiler efficiency of many appliances is expected to be less than this, with 75% a reasonable estimate. As a result the actual cost of heat at present will likely be higher in many instances meaning any savings gained would likely be higher.

The model does not take account of costs such as boiler replacement or boiler maintenance so the actual cost of a householder owning and operating a boiler is going to be greater than this. A distinct advantage of a district heating scheme is that it is centrally controlled and maintained, so reducing costs and inconvenience for householders beyond fuel costs.

The main reason why it would be attractive to heat users to purchase their heat from the heat network would be cost. This cost is the total of the network installation cost, the cost of generating the heat and the operating costs of the network. The network costs are not likely to vary once the system is operational and, if the GRREC supplies the heat it is generated from refuse collections rather than fossil

[12] Source: The Scottish House Condition Survey http://www.gov.scot/Topics/Statistics/SHCS

fuels, the cost of heat should be more predictable in the medium to long term. Householders can therefore benefit from lower cost of heat in the short term and predictable prices in the long term.

8.2.3 Capital costs

A total peak load for the scheme, including residential and non-residential demands is determined by multiplying the combined peak from all connections by a diversity factor. It is unlikely that all users have a heat demand at the same time, so a diversity factor accounts for this, reducing the peak demand and therefore the required capacity of the district heating scheme, so reducing costs. A diversity factor of 60% was used due to the large number of domestic connections, with a diversity factor at the energy centre of 60%. For domestic properties the peak heat demand for hot water (20kW to 35kW) is likely to be significantly higher than the peak demand for space heating (10kW). However since the diversity factor for hot water is significantly greater than that for space heating (fewer showers operating at the same time than heating systems) the peak load at each node is expected to be higher for space heating than hot water.

A future more detailed analysis will evaluate space heating and hot water separately and would include diversity factors at all branches of the network to optimise network design.

Table 6: Economic Model Capital Cost Inputs (additional inputs are shown in the Appendix)

Capital item	Cost	Comment
Backup boilers	£68 per kWth[13]	Capacity calculated from combined peak load. Boilers assumed to be gas boilers, located adjacent to the opportunity area at the energy centre shown in Figure 4.
Gas CHP energy centre scenario	£740 per kW[14]	Standard cost estimates for a Gas CHP plant.
Primary network pipe costs	Total installed cost of £900 per metre[15]	Assumed 300mm pipe[16] for the primary distribution network. Optimisation of the pipe sizing would lead to reductions in pipe sizes and costs. It is also possible that some sections may need larger diameter pipework, if provision is allowed for additional connections increasing costs.
Domestic property connection costs	£3,800 per household[17]	Assumed to include branch pipework from the primary network, a HIU for each property comprising heat exchanger for instantaneous hot water and a heat exchanger connecting to an already installed wet, heat distribution system. To make a district heating scheme viable, domestic connections to the network must be delivered at less cost than a replacement boiler, so the developer will ensure this and hence may subsidise connection costs.

The cost of finance has not been included in the analysis at present. At this feasibility stage, the aim is to determine financial viability through Internal Rate of Return and Net Present Value evaluation. The cost of finance will be influenced by how a project is taken forward and who would own the project, so be securing the finance for it.

13 Assessment of the Costs, Performance and Characteristics of UK Heat Networks.
14 The potential and costs of district heating networks, Poyry and Faber Maunsell, April 2009. Capital costs inflated from 2009 to 2015 prices.
15 PB Power Study 2009
16 PB Power Study 2009
17 Source: Pöyry and Faber Maunsell, The Potential and Costs of District Heating Networks, April 2009

8.2.4 Operating costs

The following operating costs were assumed for the two different district heating scheme heat sources, GRREC or gas CHP.

Cost item	Cost	Comment
Network maintenance	1.3p/kWh[18].	Sum of costs for the Maintenance of Network, HIUs and Meter. Excludes staff costs for metering, billing and revenue collection. Applies across both heat sources.
O&M backup boilers	0.445p/kW_{th}	Applies in all scenarios
O&M for gas CHP	0.8p/kWh_e	Applies for Gas CHP as heat source

8.2.5 Phasing

The phasing of a retrofit district heating scheme plays an important role in managing cash flow. It is unlikely that all heat users will be able and willing to connect to the scheme at the same time, with suitable incentives to do so.

It has been assumed that the capital expenditure (Capex) for the energy centre and the main transmission network all falls within project year 0. The capex for the local infrastructure (consumer connections) is then spread evenly across the following 5 project years. A detailed feasibility study would profile the phasing of different nodes. It is likely that housing association and landlord properties would be the first to connect with private home owners connecting as heating systems need to be replaced.

8.2.6 Energy and carbon prices

Energy and Carbon prices are taken from the Department of Energy and Climate Change Energy & Emissions Projections[19], inflated accordingly including rates for Climate Change Levy, Carbon Price Support and EU ETS.

The base case price for the heat sold to consumers from the district heating network, is taken as the price of gas, multiplied by the assumed efficiency for gas boilers, to give an equivalent price for heat of a gas system. Various scenarios varying the cost of heat, as shown in Section 8.3.3.1, were used to test the sensitivity of the viability to different heat prices. A discount of 10% and 20% on the residential cost of heat has been used to reduce heat cost to those connected to the scheme, providing an incentive to switching and cheaper heat for residents of the area.

According to a recent study, typical district heating heat prices across the market range from 4.64p/kWh to 9.88p/kWh. The prices modelled here are at the lower end of this range but is intended to test the viability of a possible district heating network which can deliver savings for consumers against domestic gas prices. For the gas CHP scenarios, the electricity price for the sale of electricity were taken from the DECC forecast wholesale electric price (inflated to the project year).

Carbon savings are determined by comparing the estimated carbon dioxide (CO_2) emissions (tonnes) for the proposed energy centre against the estimated emissions from the business as usual local domestic gas boiler case. CO_2 emissions were estimated from the standard HM Treasury Green Book supplementary guidance emissions factors[20].

8.3 Results

For each opportunity area an annual cash flow across the life of the district heating scheme was produced for the two potential heating technologies using heat from GRRECC and a gas CHP at local energy centres. This cash flow was used to calculate an Internal Rate of Return and a Net Present Value at a discount rate of 3.5% for the investment. These metrics were used to determine the financial

[18] P Assessment of the Costs, Performance and Characteristics of UK Heat Networks.
[19] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2014
[20] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

viability of the scheme and hence indicate whether a commercial developer would be interested in taking this forward.

Across each of the opportunity areas, the price charged to those households connecting to the system was initially assumed to be a discount of 20% on the cost of gas. The heat injected into the network by GRRECC is assumed to be at no cost.

8.3.1 Pollokshields East Opportunity Area

Table 7 summarises the results of the financial analysis of schemes in the Pollokshields East Opportunity Area.

Table 7: Results of Pollokshields East Opportunity Area analysis

Heat Source	Gas CHP	GRRECC
Total Capex	£22.1million	£15.5 million
Total Capacity	32MWth	25.6MWth
Annual operating costs	£769,000	£742,000
NPV	Negative	£7.1 million
IRR	<0%	8%
Carbon Dioxide Equivalent Saved (year 5 – 2021)	Negative	10,082 tCO_2e/year

From these results it is clear that the Gas CHP scheme is not commercially viable as designed. The cost of installation and operation of the scheme, is not covered by the revenue that would be generated by sales to households connected to the scheme, even if every household in the area were connected.

Significant reductions in the amount of investment required to install the system are required. One opportunity for this may be to identify sources of grant funding that would reduce the initial investment requirements. This is explored further in scenarios in Section 8.3.3.1

The scenario using heat from GRRECC is more viable, however there remains a significant technical hurdle to be overcome in that there is a railway line which would need to be crossed. This would likely come at additional capital cost. The further from the energy centre that the district heating system is located, the greater the uncertainty in the network costs. It is possible that there would be additional costs identified by more detailed analysis of the 2.5km route between the study area and the GRRECC.

8.3.2 South-West Govanhill

Table 8 summarises the results of the financial analysis

Table 8: Results of South West Govanhill Opportunity Area analysis

Heat Source	Gas CHP	GRRECC
Total Capex	£6.24 million	£4.5 Million
Total Capacity	8.7MWth	5.8MWth
Annual operating costs	£179,053	£173,677
NPV	Negative	£884,445
IRR	<0%	5%
Carbon Dioxide Equivalent Saved (year 5 – 2021)	Negative	2,355 tCO_2e/year

Again, from these results it is clear that the gas CHP scheme is not commercially viable as designed. The cost of installation and operation of the scheme, is not covered by the revenue that would be generated by sales to households connected to the scheme. However using heat from GRREC is potentially viable.

8.3.3 Govanhill Main Opportunity Area

The results of the Govanhill Main opportunity area analysis show that a district heating scheme, using heat from the GRREC has the potential to be financially viable as shown in Table 9.

Table 9: Results of Govanhill Main Opportunity Area analysis

Heat Source	Gas CHP	GRRECC
Total Capex	£39.8 million	£22.9 million
Total Capacity	69MWth	46MWth
Annual operating costs	£772,283	£744,360
NPV	Negative	Negative
IRR	<0%	3%
Carbon Dioxide Equivalent Saved (year 5 – 2021)	Negative	10,010 tCO_2e/year

This was based on the assumption that the heat from the GRREC was fed into the district heating scheme at zero cost and householders were billed at a rate 20% lower than they are paying for their heating at present. As this shows a negative NPV value, this indicates that the project would not be attractive to a commercial developer. However as it shows a positive IRR, a number of additional scenarios were modelled to identify what would be required to deliver low cost heating to the area, by varying the price charged to the householder and the level of grant funding that would be required to deliver a commercially viable scheme. The results are shown in the following section.

8.3.3.1 Govanhill Main Opportunity Area Scenarios

The table below shows the effect of different levels of grant funding and different heat prices, on the likely financial viability of a heat network encompassing the Govanhill Main Opportunity Area. In the scenarios shown, the cost of heat delivered to the householder is equivalent to the cost of heat using a condensing gas boiler.

Table 10: Govanhill Main Opportunity Area scenario with 0% savings on heating to residents

Scenario	Grant funding	GRREC Heat cost in to network (p/kWh)	NPV	Positive net cash flow	IRR
1	£ 9,000,000	0.0	£ 17,001,538	9	14%
2	£ 4,500,000	0.0	£ 12,865,249	11	10%
3	£0	0.0	£ 8,728,959	13	7%
4	£ 9,000,000	1.0	£ 10,102,073	11	10%
5	£ 4,500,000	1.0	£ 5,826,820	14	7%
6	£0	1.0	£ 1,690,530	17	4%
7	£ 9,000,000	2.0	£ 3,063,644	15	6%
8	£ 4,500,000	2.0	Negative	19	3%
9	£0	2.0	Negative	23	1%

We can see that even without grant funding, the network has a positive net cash flow after 13 years in scenario 3, where the cost of heat from GRECC is 0p/kWh. If the cost of heat rises to 1p/kWh, the payback increases to 17 years (scenario 6). As such there is a possibility of a financially viable project without grant funding, but it would not deliver significant savings for most householders, and may therefore struggle to attract heat users.

We then considered the same scenarios, but with the saving delivered to the householder set at 10%. These are shown in Table 11.

Table 11: Govanhill Main Opportunity Area scenario with 10% savings on heating to residents

Scenario	Grant funding	GRREC Heat cost in to network (p/kWh)	NPV	Positive net cash flow	IRR
10	£ 9,000,000	0.0	£ 12,467,942	10	11%
11	£ 4,500,000	0.0	£ 8,331,653	13	8%
12	£0	0.0	£ 4,195,363	15	5%
13	£ 9,000,000	1.0	£ 5,429,513	13	7%
14	£ 4,500,000	1.0	£ 1,293,223	17	4%
15	£0	1.0	Negative	20	2%
16	£ 9,000,000	2.0	Negative	20	2%
17	£ 4,500,000	2.0	Negative	>25	0%
18	£0	2.0	Negative	>25	<0%

There are a number of conclusions that can be drawn

1) In scenario 12 we can see that a payback of 15 years is possible with no grant funding but only if the cost of heat is 0 p/kWh.
2) Where the cost of incoming heat is 1p, £9million of grant funding is required for a saving to be delivered.

Finally we can see from Table 12 that it may be possible to deliver a 20% saving to householders if significant grant funding is obtained and the incoming heat is provided for between 0p/kWh and 1p/kWh.

Table 12: Govanhill Main Opportunity Area scenario with 20% savings on heating to residents

Scenario	Grant funding	GRREC Heat cost in to network (p/kWh)	NPV	Positive net cash flow	IRR
19	£ 9,000,000	0.0	£7,934,346	12	9%
20	£ 4,500,000	0.0	£3,798,056	15	6%
21	£0	0.0	Negative	18	3%
22	£ 9,000,000	1.0	£895,917	16	4%
23	£ 4,500,000	1.0	Negative	21	2%
24	£0	1.0	Negative	>25	0%
25	£ 9,000,000	2.0	Negative	>25	<0%
26	£ 4,500,000	2.0	Negative	>25	<0%
27	£0	2.0	Negative	>25	<0%

8.4 Conclusions

The scenario analysis completed on the Govanhill Main Opportunity Area indicates that there is potentially an economically viable district heating scheme that could be developed to provide low cost heat to householders. Adjusting the level of grant funding, savings delivered to heat consumers and the price paid to GRREC for heat, concluded that a district heating network can deliver low cost heating to domestic householders in the area.

Heat can be delivered to the 3,400 properties in Govanhill Main, at a price 20% below the cost of heat from a domestic gas boiler, while delivering a payback of under 15 years to the district heating network operator. To enable this, grant funding of between £4.5 million and £9 million is required, depending on the level of financial return offered to the network operator. Without grant funding a network is viable but is not able to deliver heat at as low a cost, which would mean that fewer people were removed from fuel poverty.

The other opportunity areas identified are not economically viable as standalone networks, however if the Govanhill Main Opportunity Area were to be developed, the cost of connecting the other opportunity areas to this network would become significantly reduced and could make them viable. This would become apparent from a detailed feasibility study.

There are many variables in the analysis that need further discussions and engagement with the various stakeholders involved to determine whether these scenarios could be made to work. Support would be required from Scottish Government, Glasgow City Council, Viridor, Govanhill Housing Association and the residents of the Opportunity Areas.

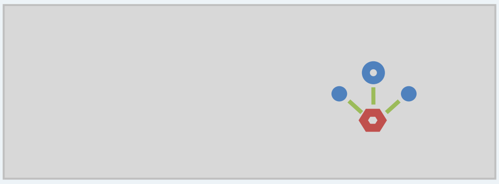
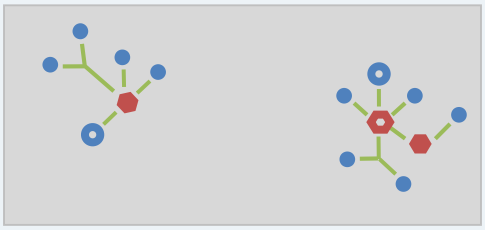
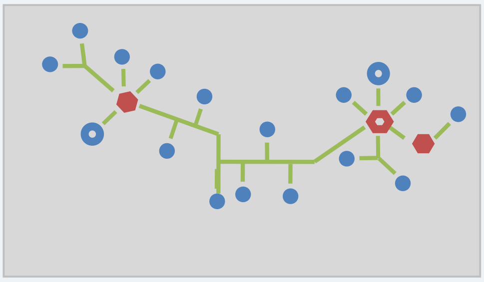
The next steps in taking this project forward are to engage with each of the stakeholders to identify any barriers that they may have to exploring this opportunity further. The next stage in the development of the scheme is to complete a detailed feasibility study of the Opportunity Areas identified, which is likely to result in the areas changing. This will require information and engagement from each of the stakeholders listed.

9 Heat masterplan

The development of a district heating scheme of the size outlined in this study, will take place in phases over a number of years. As each phase expands the heat network, so the stability of the heat network increases due to the increasing diversity of connections to the network. This phased approach allows the most cost effective areas to be connected to the network first, with the subsequent cost of connecting to less cost effective areas being reduced significantly so making them economically viable.

Figure 24 presents how a district heating network evolves over time.

Figure 24: District Heating Network Development Timeline

Stage 1 – Initial Development	Stage 2 – Expansion (0 – 10 years)
 Govanhill Main Opportunity Area developed based around key anchor loads (i.e. tenement blocks, social housing, Holyrood School) and other loads in the vicinity.	 Pollokshields East OA developed and GMOA expands as it becomes more established to connect additional loads that have become economically viable since Stage 1. GRREC reinforced with additional heat sources (e.g. gas CHP)
Stage 3 – Interlinking (10 – 15 years)	**Key**
 Inter-connectors installed to share excess heat capacity between clusters in Pollokshields East and Govanhill Main. Inter-connector routes selected to permit further connection with economic demands situated between clusters such as St. Bride's Primary School.	Heat Load; Anchor Heat Load; Heat Producer (Small); Heat Producer (Large); Heat Distribution Pipework

The Govanhill Main Opportunity area would likely be used as a starting point for a district heating network delivering waste heat from the GRREC to other areas of the study area. Once this network is established, future expansion into further residential blocks to the north of the Govanhill Main Opportunity area up to Cuthbertson Street, between Langside Road and Pollokshaws Road could be viable based on the high heat demand in these areas. Additionally, commercial sites such as 'The Gym' to the north east would be a suitable heat source to connect.

To the west the Govanhill Main Opportunity area could expand towards the Pollokshields East Opportunity Area. From here it would be possible to extend the network to Hutcheson's Grammar School to the south or to integrate the St Andrews drive area to the north.

As the capacity of the network grows, addition heat sources, such as gas CHP can be added, providing increased redundancy and security of supply to the network.

10 Commercial arrangements

Selecting the appropriate technologies to provide low carbon heat is only part of the solution, identifying successful district heating supply and management solutions that align with the requirements of the different ownership models is as important to the successful delivery of a low carbon low cost heat.

In October 2015 ChangeWorks published "Identifying the Fair Share: Billing for District Heating". This research explored the experiences of social housing district heating schemes from the landlords and residents perspective. As recently completed research into the impacts of different management and metering schemes used in district heating schemes, it is very relevant to this study. This report found that landlords had taken two different approaches to billing tenants for heat, either on a fixed fee or variable rate. There was no consensus on whether a fixed fee or variable rate approach was optimal; landlords had experienced successes and difficulties with both. Fixed fee approaches were favoured for ensuring residents received an adequate level of heat and minimising concern about heating bills; variable rate approaches were favoured for helping residents save heat and pay only for what they use.

However a number of challenges were often faced by landlords with both approaches including: difficulty setting prices, managing debt and disconnection, and high administration costs. Residents had different preferences in terms of billing methods. Those on fixed fee billing were more likely to find their home easy to keep warm and their heating bills affordable than those on variable rate billing.

Residents' preferences of how they paid for their heat (e.g. prepayment, direct debit, credit billing and heat with rent) also varied. Prepayment was the option with highest dissatisfaction rates, but in contrast some residents preferred it as it allowed them to budget. Similarly, some of those on heat with rent payments disliked the fact they had to pay for heating over the summer months and would have preferred a prepayment method. Overall, the most successful approach is likely to be where residents were provided with multiple options, since preferences vary.

10.1 Heat meters

Heat meters are required in district heating schemes to monitor heat use and in some cases, to bill residents. Overall, meters were considered useful although landlords had not always utilised the data available to monitor schemes. Furthermore, many had experienced problems with the meters including: transmission difficulties, residents tampering with them and high installation or maintenance costs. These challenges are particularly acute given metering requirements through the Heat Network (Metering and Billing) Regulations 2014. However, it is also expected that the new regulations may prompt the market to develop, ensuring better choice and quality of meters.

10.2 Billing

Social landlords had also taken different approaches to managing the billing of schemes: managing in-house or by a third party. Mixed experiences were evident across both approaches. Some of those who managed billing in-house felt they had lacked expertise, capacity or a joined-up approach. The learning curve some landlords experienced as a result of managing projects had meant most problems were later rectified and future schemes may be easier to manage. Those who outsourced management were largely reliant on the quality of the contractor which reportedly varied, and some struggled to find a suitably experienced organisation.

10.3 Resident understanding, advice and engagement

Throughout the research it was evident that many residents had a poor understanding of district heating; for example, residents did not always understand how the billing was set up or how to use the heating controls effectively. Some residents on fixed fee were unaware of how this worked and some on variable rate billing did not understand why unit prices were higher in district heating schemes compared to gas central heating as a result of the billing being for heat supplied rather than gas used. Most residents had received advice and whilst it was usually considered to be useful, many felt that it could have been easier to understand or more practical.

This lack of understanding has the potential to hamper the success of heating networks in the study area, so comprehensive community engagement, supported by organisations such as South Seeds is an essential part of the network development.

A minority of landlords consulted residents during the design and set up their schemes. For example, gathering resident preferences to inform the billing approach taken. These landlords felt consultation was successful in gaining buy-in for the scheme and in designing a scheme that would work.

Finally, most residents were satisfied with their district heating scheme with over 75% of those surveyed saying they preferred it to their old heating system.

Appendix A

In addition to the assumptions included in the body of the report, the following assumptions were included in the district heating economic model.

Economic Model Input	Value
Initial Model Year	2016
Discount Rate	3.5%
Residential Boiler Heat Efficiency	91%
Residential Boiler Lifetime [Years]	15
Residential Boiler Capital Cost [2015 £]	£2,816
Residential Boiler O&M Costs [% of Capex]	8.00%
Existing non-residential boiler Heat Efficiency [% GCV]	81%
Existing non-residential boiler Lifetime [Years]	15
Existing non-residential boiler Capital Cost [2015 £/kWth]	£50.70
Existing non-residential boiler O&M Costs [% of Capex]	6.67%
Back-up Boiler Heat Efficiency [% GCV]	85%
Back-up Boiler Availability	100%
Back-up Boiler Lifetime [Years]	30
CHP Under sizing Factor	50%
CHP Production Factor	70%
CHP Availability	80%
CHP Electrical Efficiency [% GCV]	38%
CHP Heat Efficiency [% GCV]	42%
CHP Lifetime [Years]	15
Third Party Heat Source Availability (GRREC)	90%
Network Heat Losses	10%
Diversity Factor	40%
Network Parasitic Electricity Consumption [% Heat Demand]	1.9%
Domestic Branch Cost per connection	£1,500
Domestic HIU and Heat Meter	£2,300
Inflation series	Quarterly National Accounts March 2015
Natural Gas Carbon Emissions (GCV)	0.19 tCO2/MWh
Electricity Generated Carbon Emissions (2015 only)	0.31013 tCO2/MWh
EU ETS Price (2015)	4.631 £/tCO2
CPS Price (2015)	15.9475 £/tCO2
Wholesale Electricity (2015)	5.340 p/kWh
Retail Electricity Non-residential (Services) (2015)	10.689 p/kWh
Retail Electricity Residential (2015)	16.108 p/kWh
Retail Natural Gas Non-residential (Services) (2015)	3.200 p/kWh
Retail Natural Gas Residential (2015)	4.766 p/kWh

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