Climate Neutral (Glasgow City) Innovation District

Final Study Report

University of Strathclyde

15 September 2021

5200737-PM-REP-002-A03

Notice

This document and its contents have been prepared and are intended solely as information for University of Strathclyde and use in relation to Feasibility Study for CNGCID. Atkins Limited assumes no responsibility to any other party in respect of or arising out of or in connection with this document and/or its contents.

This document has 79 pages including the cover.

Document history

Document title: Final Study Report

Document reference: 5200737-PM-REP-002-A02

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
A00	Draft Issue for comment	EM/JG/MH/TM/ RM (SGS)	MG	EM	MG	26/07/21
A01	Final Issue for comment	EM/JG/MH/TM/ RM (SGS), HA (Ikigai)	MG	EM	MG	26/08/21
A01.1	Final Issue (Key findings Inclusive) for comment	EM/JG/MH/TM/ RM (SGS), HA (Ikigai)	MG	EM	MG	06/09/21
A02	Final Issue post comments	EM/JG/MH/TM/ RM (SGS), HA (Ikigai)	MG	JG	MG	10/09/21
A03	Inclusive of Funding and bankability V2 issue.	EM/JG/MH/TM/ RM (SGS), HA (Ikigai)	MG	JG	MG	15/09/2021

Client signoff

Client	University of Strathclyde
Project	Climate Neutral (Glasgow City) Innovation District
Job number	5200737

Contents

Tables

Figures

Executive Summary

The District Heat Network '100% uptake' Scenario provides a credible pathway to 84% emissions reduction from baseline, and innovative grid flexibility approaches can offer a further 9% reduction. These measures coupled with some residual GHG emissions capture technology (and nature-based solutions) provide a pathway to Net Zero by 2030.

A new vision of a series of climate corridors has been developed. Meaning a transformation of city streets to carry 100% low carbon heat, power, transport, greening and wellbeing services. A reforming of the arteries of the city with people's wellbeing as a priority.

Overview

Atkins were commissioned with specialist partners; COMSOF, STAR, Minibems, Smarter Grid Solutions, Ikigai and Energy Systems Catapult, (ESC), to undertake a feasibility study to review the Energy, Transport and Environmental greenhouse gas emissions from the 'Innovation District' of Glasgow, referred to as the Climate Neutral Glasgow City Innovation District (CNGCID) throughout this report. This district is bounded by the M8 North and the River Clyde to the south. The district is largely centred around High Street, with main energy consumers within the central business district that includes St Enoch Shopping centre and much of Argyle Street.

The aim was to determine a feasible roadmap of technical and financeable solutions to achieve a climate neutral district, where possible targeting 100% renewable energy, transport and sustainable places and inclusive of adaptation to the impact of climate change. A climate Neutral District has been achieved by determining a carbon equivalent baseline case for 2020, followed by a number of collaborative workshops, optioneering studies and industry engagement to select the most feasible roadmap.

In addition to the collaboration of delivery partners, a steering group was formed to support providing experience and knowledge on the local policy, geography and social aspect specifics. The steering group, formed of **Scottish Enterprise, Wheatly group, Zero Waste Scotland, Scottish Water Horizons, Scottish futures trust, Clyde Gateway, Clyde and Green valley network, Climate ready Clyde, NHS, Local energy Scotland, Sustrans Scotland, SPEN, Salix**, have complimented and advised throughout the study with many thanks from the study's delivery partners.

Baseline Emissions

The carbon equivalent baseline was developed for the district boundary, assessing buildings, transport, environment, climate risk and electrical gird capacity. The buildings baseline model, LEAR 1 was modelled by ESC using building archetypes from UK referenced data. This was supported with real metered data where available for major loads and refined using sensitivity analysis. The quality and accuracy of the data was supported through an extensive data gathering exercise, closely supported by the Steering group.

Once the LEAR 1 model and baseline report was [1] complete, the work focused on four respective sectors to decarbonise the equivalent carbon emissions, as follows:

I. Building
II. Environmental (social value & sustainable places)
III. Transport
IV. Electrical Grid Capacity and Flexibility

Building associated emissions are the majority contributor of the 2020 baseline, at 82.1ktCO_2e/yr against the district total annual emissions of 88.3ktCO_2e (or 92%). In the 2020 LEAR 1 case these are largely from gas emissions, where homes are mainly central boiler heated and some through simple electrical resistive heating. The carbon equivalent emissions associated with gas and electricity in 2020 are **0.184 & 0.138 kg CO_2e/kWh** respectively (from BEIS published values, as used in the baseline report [1]). By 2030 the electrical grid averages have decreased to **0.051g/kWh for** electricity[1], but the carbon emissions from gas in 2020 to 2050 are expected to stay largely the same. To tackle these emissions, the ESC modelled several 'best in class' energy efficiency measures based on other UK cities. This approach was coupled with an understanding of Glasgow's historical building archetypes, supported by stakeholders. This included maximizing insulation levels, window glazing, heating controls, 'smart home' tech. The combined package of energy efficiency measures was shown to reduce overall heat demand by ~30%.

[1] Using BEIS updated July 2021 values.

Scenario Evaluation

Two scenarios were then proposed to offer at scale decarbonisation. The first was a hydrogen-based pathway, which assumed increased volumes of H_2 in the national grid as campaigned by UK government in the recent 10-point plan, but also local projects such as Project Acorn, led by Pale Blue Dot. This scenario, Scenario 1, offers **~37% GHG reduction** (cumulative with energy efficiency measures) but leaves the CNGCID with a considerable challenge to reach Net Zero, particularly by 2030. For this reason, Scenario 1 was not explored further, and served as a counterfactual to the main study work, Scenario 2.

The second, and recommended, scenario built on the Heat Vision 2030 work led by COMSOF, STAR and Minibems (e.g. Queens Quay Clydebank Low Carbon Heating Scheme), and proposed four heat pump modules in the River Clyde close to Glasgow Green, providing centralised supply within the district to decarbonise the heat demand. The proposed scheme would be constructed in two phases, first focusing on secure heat 'takers' such as the hospital and University and later, in phase 2 moving to very high levels of adoption across the region (targeting 100%). This second scenario enables deep decarbonisation of **75% reduction from baseline**. The 'carbon residuals' are dependent on the level of electrical grid carbon intensity (particularly in South Scotland region)[2]. There is potential for the residuals to be very low, given South Scotland already has one of lowest carbon intensities across the UK.

Additional Considerations

The environmental improvements considered in this report delves a lot deeper than the potential to offset net carbon equivalent emissions. The measures proposed and discussed, offer risk mitigation against the potentially severe effects of climate change, and enable a green, car free city that can offer a thriving economy, wellbeing and ultimately quality of life. Emissions contribution can offer **-0.1ktCO_2e/yr carbon offsetting,** and this carbon absorption has a potentially infinite life. The compound effect over a lifetime is therefore significant (e.g.8kt over an 80-year life).

The transport emissions are a significant source of carbon emissions, and other unwanted effects (noise, air pollution) but relatively small in overall baseline, at 6.2 of the 88.3ktCO_2e/yr total (or 7%). Through a number of measures complimentary to existing Glasgow wide transport planning (including active modes, increased public transport, demand management, digital tools, uptake of zero emission vehicles), and long-term decarbonisation plans, it has been shown that reductions of **~57% reduction are possible by 2030**.

In parallel to the carbon emissions focussed work, our partner SGS reviewed the electrical grid capacity and flexibility for Scenario 2 (~23MW heat pump demand). This work was to address the question of whether the existing network can support the new electrical demands, but also to understand what flexibility exists, and can be introduced to mitigate reliance on the grid during carbon intense periods (e.g. typically between 4pm and 7pm). The study found that modelled electrical demand can be met within existing capacity, and there is no urgent need for Active Network Management (ANM) although there are long-term benefits of this. In addition, introducing rooftop Solar PV (up to 24MW possible) and 6MW battery storage (with inherent DHN system flexibility) can offer good flexibility to the system, reduce energy demand and offer a 9.4% reduction in grid carbon.

[2] These have been based on the BEIS July 2021 published values. Available through the UK Government Green Book.

Carbon Emissions

The aggregated carbon emissions discussed in Scenarios 1 and 2 is presented in Figure 0-1 below:

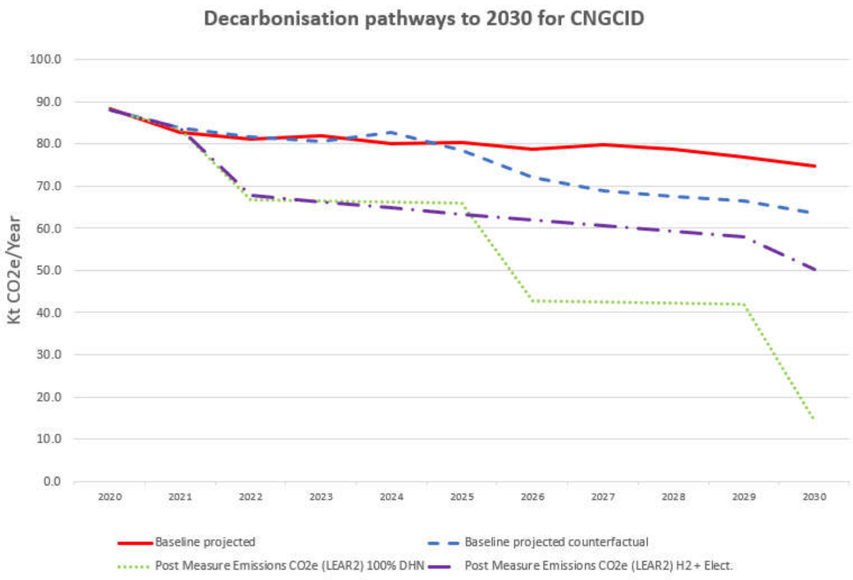


Figure 0-1 - Aggregate Carbon Emissions 2020 to 2030

Section 7 of this report explores the order or prioritisation of each decarbonisation measure identified. The recommended order is not to show relative importance or contribution to the 2030 Net Zero target, but rather to show the series of steps needed to achieve the overarching goal. This study has taken a 'whole systems' approach to achieving a credible Net Zero pathway for the CNGCID, and some of the enablers to this pathway need prioritised in the short term. For instance, the environmental measures and package of building efficiency measures need to be prioritised in the short term, as the earlier these are adopted the greater effect they can offer. Also, they provide indirect support for a Net Zero pathway, by engaging the public and encouraging community action. From this prioritisation work, against the criteria considered, the Scenario 1 (H_2 blending in grid) was considered least credible within the project timescales and discounted from further financial study review.

Financial and Commercial

The commercial and finance aspects of this study were focussed on in the latter phases of the project, through a series of workshops and discussions. For Scenario 2, 100% DHN case, a cash flow model was developed to understand the investment profile over 25-year and 40-year time frames. It was found that the strongest influencers on the investment case are:

- Inflation, which was assumed at 2%
- Tolerable heat pricing, which to achieve a minimum IRR of 8% was found to be ~15p/kwh (considered too expensive in the current market)
- Design life before major overhaul. It was essential to maximise life of the asset through higher than typical annual OPEX costs, this means a 30-year design life is achievable and so pushes back the timescales for replacement of major components.
- Agreeing a very competitive electrical price per unit (kwh), which is likely achieved through private wire agreement or investing in commercial Power Purchase Arrangements (PPA) to secure fixed low carbon production. A price of 5p/kWh is desirable, which is 50% of current market standard (BEIS figures). Yet there are Scottish based precedents for this.

In response to the question of "how to finance the project?", Ikigai undertook a high-level review of investor considerations and potential structures for the proposed district heat network to serve the CNGCID. This is outlined in the technical memo [2], and supported through a bankability workshop, with Steering group members [3].

Funding and Bankability

The Project has the potential to be, if developed taking into account key bankability concerns identified, attractive to institutional investors for the following reasons:

a) a stable, creditworthy, existing anchor heat (and power) load, which could result in the long term contracted inflation-linked revenues which institutional investors seek, while still delivering best value to the customer;

b) a diversified customer base capable of growing over time within, and beyond, the boundaries of the GCNID, absorbing new, lower cost, sources of low carbon heat (and power) supply – this can create the economies of scale on demand required to 'sweat' the network assets, secure best terms from contractors, smooth inter-seasonal demand, while reducing disconnection, volume and insolvency risk;

c) a strategy for delivering additional zero carbon heat generation, while transitioning existing (currently more cost effective and technically proven) CHP generation to optimise the system, amortise existing investments and eliminate the risk of additional capex or opex associated with future carbon regulation (i.e. 'stranded asset' risk); and

d) an holistic, integrated approach to infrastructure – digital/broadband, metering and energy efficiency, power generation and heat generation/capture, EV charging and flooding related adaptation measures – development, procurement and rollout, which could result in a more economically efficient solution through data-led design, coordination of physical works, infrastructure sharing, stimulating competition and consortium building and future-proofing.

At this early project phase, it is difficult to determine the exact funding / shareholding structure that will be appropriate for the CNGCID project. However, some of the credible finance models suggested include the following:

- Early incorporation of a limited liability company for the sole purpose of developing the Project (the "Project SPV")– legal advice will be required to determine the optimal corporate and governance structure.
- Make any public grant or debt funding (if available) conditional on satisfying requirements with respect to (i) affordable and reliable heat to be made available to residential heat consumers; (ii) Net Zero targets; and (iii) local content, ensuring that the covenants imposed are realistic and achievable.
- Maximising leverage to the extent there is a pricing advantage (i.e. equity) made available to the Project company.
- Consider refinancing of higher cost construction capital 12-18 months post-commissioning to facilitate investment by funders whose investment mandate is limited to operational assets.
- Adopt a "generator build" model which consolidates ownership of the energy centre, primary and secondary heat and electrical networks and customer connection equipment under a holding company, but also provides (e.g. by way of separate subsidiaries) for refinancing (whether by way of debt and/or equity) of "esco" and/or "pipeco".
- Offering a comprehensive security package to all debt providers, in particular over assets which may have residual value in circumstances where the project does not become operational (i.e. real estate).

To inform which model may be the best route forward, a series of recommended steps are presented in the technical memo [2], including detailed private sector investor engagement exercise.

Leading the Way

Throughout the study the culture amongst the valued stakeholder group has been to facilitate open, innovative discussion. To this end, this study captures opportunities and ideas that are considered 'Leading the Way' in decarbonisation action, and potentially very ambitious within the project timescales of Net Zero by 2030. These additional measures could offer a best if class solution, with several additional benefits. Measures in this section, include:

- Utilising innovative virtual power platform (VPP) technology to reduce carbon intensity of the grid by up to 9% (see Section 5), e.g. Maximising the benefit of BESS
- Enhanced building control of heating through Minibems technology (discussed in section 3.5.3) can offer maximal COP performance, and therefore greatest value per unit electricity from the Grid
- Enhanced thermal storage can offset the need to use carbon intensive electricity
- A consortium of Stakeholders could invest in Direct CPPA (Corporate Power Purchase Agreements) to offset demand through investment directly in procured clean generation
- Additionality measures should be maximised (e.g. DAC and Solar PV)
- Additional heat sources (as discussed in Section 3.5.4) should be investigated as a priority to see if they can reduce the central WSHP thermal demand. From initial reviews, this could offer ~10MWth.
- DAC technology as a mean to capture CO_2 residuals. Technology could be installed early though to additionally offset CO_2 emissions.

This early study to explore decarbonisation pathways for the district has proved valuable in identifying UK first-of-a-kind approaches to urban environmental improvements. Moreover, the energy scenarios explored provide credible pathways to Net Zero and a clear development timeline. The study has also identified key constraints and potential 'red flags' to a DHN project.

The high uptake (targeting 100%) DHN scheme can offer **-84%+ ktCO_2/yr step change reduction** to carbon emissions, taking total emission in 2030 to **14.2 ktCO_2/yr.**

This scenario requires action urgently to integrate such large-scale infrastructure change with existing initiative like the Avenues project, the opportunity to integrate two city scale infrastructure projects is unique offering a “one time only” opportunity. The decarbonisation measures proposed by sub sector (Buildings, Environment, transport) offer solutions that not only help meet Net Zero by 2030 but have many indirect benefits.

Key Findings

Achieving Net Zero status for the GCCNID is possible with a reinvigorated level of ambition and urgency. To best use this work, would be to act as a springboard to the next part of the project lifecycle. To enable this, five overarching actions should be prioritised, as follows:

- Avenues project integration; enhancement and expansion of the existing planned Avenues programme. The inclusion of High Street as the key north-south spine is critical to fully realising the wide range of benefits of an integrated climate corridor network across the CNGCID.
- Improving Building efficiency to maximum achievable levels of thermal performance is a key enabler to any future 'step change' decarbonisation pathway, such as a city wide DHN scheme. This needs actioned in the immediate term.
- DHN next steps: Glasgow City Council must approach how they will de-risk a project of significant infrastructure scale by appointing a task force to establish the appropriate legal structure of an organisation to manage the project technically and commercially.
- 'Avoid, switch and improve' approach is needed across transport use, to reduce fleet emissions and switch public services to Net Zero. Walking and cycling use will have long-term benefits in wellbeing, health and city culture. These systems require to be implemented consistently across the city.
- The climate change related risk of increased flooding, both river and surface flooding, urgently needs to be addressed with a strong climate sensitive approach to urban environmental improvements. This should be informed by best practice
- Increasing vegetation cover, green space, and using innovative, best practice measures to naturally sequester carbon is an important means of achieving Net Zero within CNGCID. Extensive implementation of climate corridors is needed, and a green infrastructure led approach to all planned development.
- The Project has the potential to be attractive to institutional investors.
- The district should not need be treated as an island. The city's decarbonisation roadmap provides opportunity for this model to scale and to replicate across the whole city. This includes connecting communities and businesses in geographically separate location. This technical work has shown that the natural heat resource in the River Clyde exists to enable this

Key Facts & Figures

- **73.9kt** CO_2e emissions reduction achievable (**84%** from current baseline)
- **£210m** for total cost of transition
- Approx. population of **17,000** permanent residents within district
- **35 km** of pipework needed
- Up to approximately **1,200 trees** to be planted
- **137,350 m^2** of roof mounted PV potential within district
- River Clyde capable of providing more than **2,000 GWh** annually, **~8%** used in GCID
- **53 GWh** electricity required for the DHN annually

Figure 0-2 - Key Metrics to Achieve Carbon Neutrality Within the District by 2030

Introduction

Background

The University of Strathclyde, in collaboration with Glasgow City Council and supporting stakeholders, has commissioned a feasibility study to determine how best to combine a set of innovative solutions that together make the Glasgow City Innovation District a **climate neutral district**. The work focusses on a 'whole systems' approach within the defined area, along with the benefits that the surrounding areas can harness from this work.

For this project, 'climate neutral' is defined as 'Net Zero greenhouse gas emissions'. According to the Committee on Climate Change (CCC) definition, Net Zero emissions means that the "total of active removals from the atmosphere offsets any remaining emissions from the rest of the economy." That is:

A climate neutral district is one in which greenhouse gas emissions to and removals from the atmosphere are balanced, such that the district does not make a net negative contribution to climate change, while assuring climate resilience for the district.

As defined in the climate neutral and boundary definition technical memo [4], climate neutral for the purposes of this report can be considered synonymous with 'carbon neutral', as the priority focus is on CO_2 removal (by 2030).

The study boundary is identified in Figure 0-3. The Climate Neutral Glasgow City Innovation District (CNGCID) boundary forms the geographic boundary for the purposes of accounting for the GHG emissions and removals attributable to sources and scopes considered throughout the study for both the baseline and 2030. There is potential for certain interventions to include assets which, for technical or financial reasons may be best located slightly outside the CNGCID, such as heat pump system technology located in/near the Clyde. Where this is the case, the boundary has been extended to include these assets.

The importance of communities located around the boundary of the CNGCID is also noted. Social justice and access to clean heat, power and resilient services has informed this work. Further information on the climate neutral and boundary definitions is found in Technical Note [4].

Purpose

The purpose of this report is to summarise the main findings and recommendations from the study, which has identified, within the CNGCID boundary, the technical and financeable solutions to achieve energy carbon neutral operation by 2030 (against defined 2020 baseline).

The report is split into the following sections to capture the key messages associated with each of the measures:

- Environment & Climate resilience
- Building Scenarios; including energy efficiency measures and discussion of scenarios
- Electric grid / Smart city characteristics
- Transport
- Carbon neutral roadmap (for selected scenario)
- Leading the way; targeting climate neutral by 2030?
- Financing and deliverability

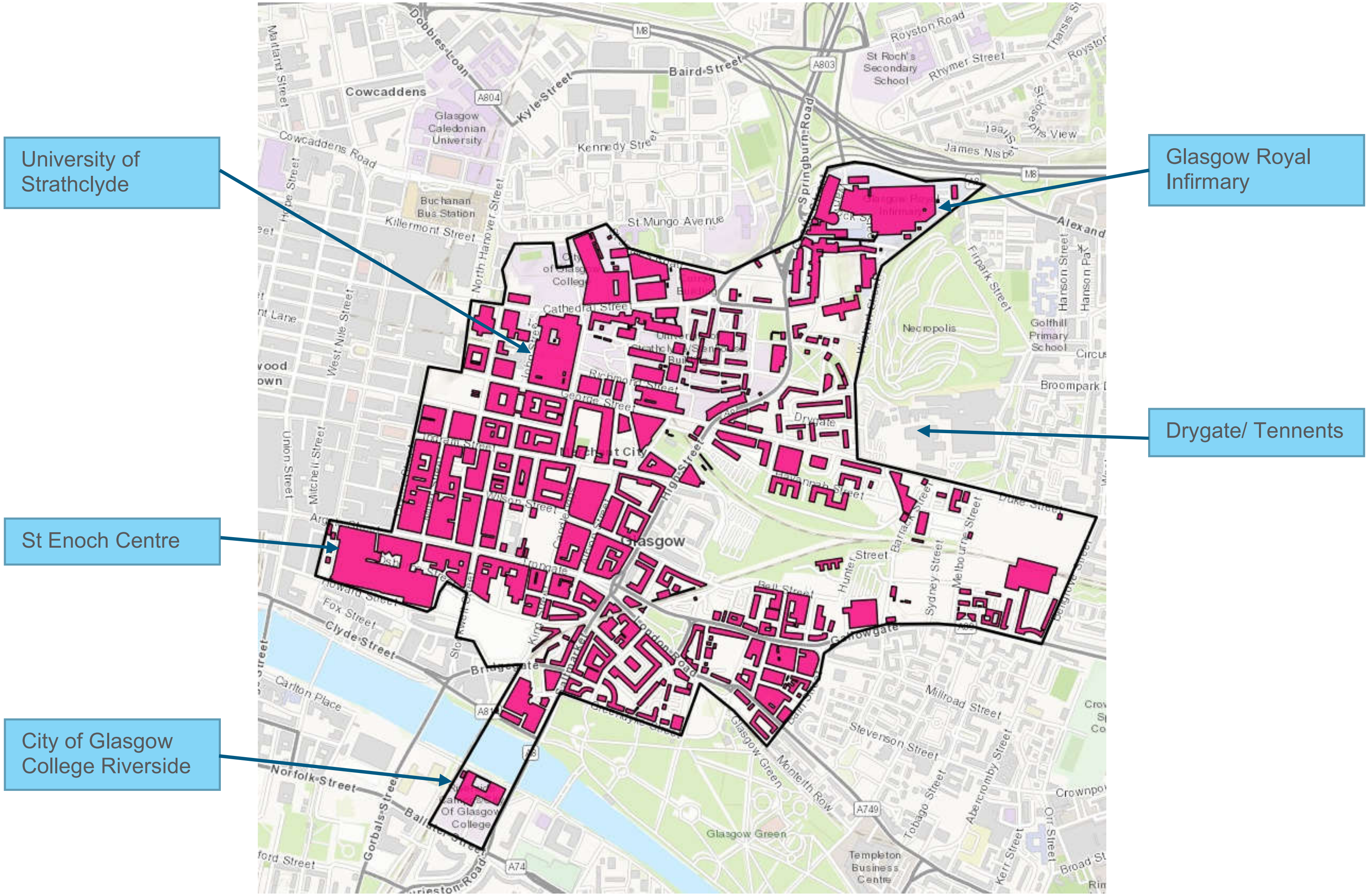


Figure 0-3 - Glasgow City Innovation District Study Boundary

Delivery Partners

This report was funded and commissioned by the University of Strathclyde, working with Glasgow city Council, to determine the best approach using a combination of innovative solutions to make Glasgow City Innovation District climate neutral.

The work would not have been possible without the support of the extensive stakeholder input (including **Scottish Enterprise, Wheatly Group, Zero Waste Scotland, Scottish Water Horizons, Scottish Futures Trust, Clyde Gateway, Clyde and Green Valley Network, Climate Ready Clyde, NHS, Local Energy Scotland, Sustrans Scotland, Scottish Power Energy Networks (SPEN), Salix**)

The Glasgow City Innovation district, anchored by Strathclyde, is a partnership between Glasgow City Council, the University, Scottish Enterprise, Glasgow Chamber of Commerce and Entrepreneurial Scotland and is home to innovative companies and organisations, as well as UK Catapult centres and Scottish Funding Council innovation.

Atkins, a member of the SNC-Lavalin Group, is a multi-disciplinary design, engineering and project management consultancy. They have been involved with this study since its inception and have led the development of the assessment, having issued technical notes on the baseline data set for the district, building modifications and transport scenarios. Atkins has worked with each of the stakeholders to develop the relevant sections of the report.

Energy Systems Catapult (ESC) is an independent, not-for-profit centre of excellence who look to bridge the gap between industry, government, academia and research. They have been involved in developing the dataset and generating the LEAR models used in the analysis of the region. This has allowed a whole system view of the different initiatives, by combining the appropriate measures and initiatives from 2020 to 2030 to understand the impact on carbon emissions.

COMSOF has more than 20 years' experience in GIS based optimisation and has been engaged in the planning and design of the district heating network. Their work has involved using the data generated by ESC to understand the heat demands in the district. This has allowed indicative pipe routing and costs to be generated which feed into the overall options analysis for GCID.

Star refrigeration is a manufacturer of heat pumps and have provided expertise on the technology throughout this assessment. They have been engaged on assessing the requirement and sizing for heat pumps in the area, and this output feeds into the district heat network design. Star are working in partnership with Minibems. Minibems is a demand management system for complex heating systems that enables improved efficiency and fuel cost savings thanks to intelligent control and monitoring technology, paired with integrated billing.

Smarter Grid Solutions is an enterprise energy software company who provide products which are used to manage power grids and market participation in energy systems in the form of distributed energy resources assets. They have contributed to this assessment through their analysis of the grid and the impact of the potential connection capacity and constraints. This ultimately influences the measures that are recommended for implementation.

Ikigai Capital provide strategic advisory services, identifying growth capital and project funding opportunities for international investors. Ikigai have supported the finance and bankability aspect of this report.

1. Methodology

Atkins has defined the overall process to develop a robust energy masterplan under five key stages, as per Figure 1-1.

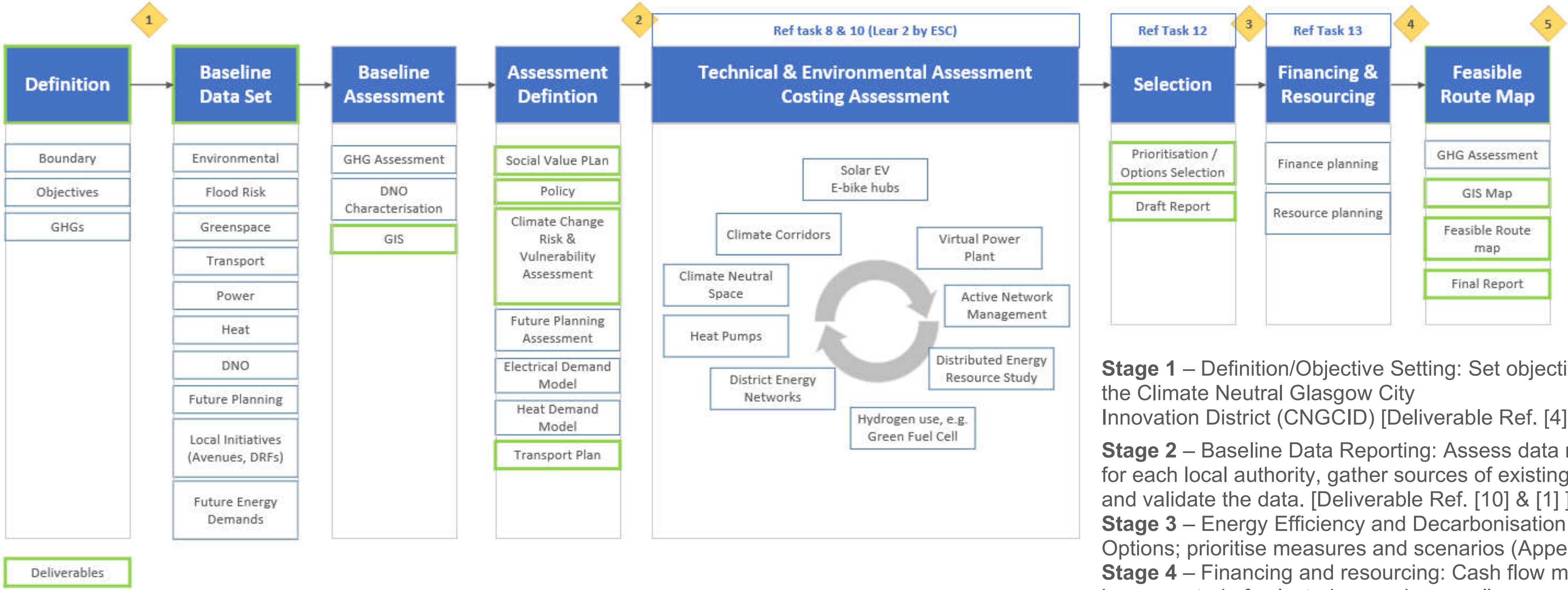


Figure 1-1 - Methodology and Deliverables Workflow

[This final report is a signposting report, which offers the reader a concise view on the method, analysis and outcomes of the CNGCID study, it should be read in conjunction with the supporting deliverables issued throughout the study]

Stage 1 – Definition/Objective Setting: Set objectives for the Climate Neutral Glasgow City Innovation District (CNGCID) [Deliverable Ref. [4]]

Stage 2 – Baseline Data Reporting: Assess data needs for each local authority, gather sources of existing data and validate the data. [Deliverable Ref. [10] & [1]]
Stage 3 – Energy Efficiency and Decarbonisation Options; prioritise measures and scenarios (Appendix C)
Stage 4 – Financing and resourcing: Cash flow model to be presented of selected scenario as well as narrative on the route to successful funding/deliverability.

Stage 5 – Route map & Implementation: This final report presents the conclusions from the study and presents a route map to 2050.

The updated GIS portal allows access to the study outputs spatially within boundary. [accessible here with approved login; http://strath.atkinsgeospatial.com]

The boundary definition, baseline definition, and assessment are captured in detail within the Baseline Data Report '5200737-PM-REP-002 A01 CNGCID' [1], issued March 2021, so will not be covered in detail in this report.

The technical and environmental assessment considered numerous (100+) measures within the subsections of this report, including:

- Building measures; Building fabric material upgrades,
- Smart Grid Flexibility
- Transport measures: Solar PV, EV, and e-bike hubs
- Environmental measures: climate corridors, vertical gardens, green spaces, allotments, River Clyde initiatives, flood drainage.

These measures were discussed, screened and assessed by sector specialists The Energy Systems Catapult (ESC). The Building measures were introduced to the ESC LEAR modelling software and the approach has been summarised in a technical note [5]. The output of this modelling exercise was used to inform the aggregate carbon modelling, smart grid flexibility work and update the live GIS platform.

A GIS platform was created for the area, and this is a web-based data visualisation and analysis tool which shows the impact of the scenarios assessed for the region. Electricity and heat demands are shown for each of the buildings, making this a very useful tool to help provide understanding of the options available to the region. This can be accessed through the following link: https://strath.atkinsgeospatial.com

For each of the areas listed above, technical notes were produced which summarised the suitability to the region and included recommendations on how CNGCID could contribute and influence their development. Smart grid solutions completed the assessment on the smart grid system, while STAR was engaged when assessing the heat pump options and COMSOF was involved with the assessment of the DHN routing. Key messages have been summarised in this report.

A social value plan was developed and more information on this is detailed within the issued Technical Note (5200737-EN-MEM-003 CNGCID SVP [6]).

Following review of the available measures for implementation, the measures were considered within two credible net zero pathways or scenarios:

Hydrogen in NTS grid (up to 20% volume) and localised electrification of heat
100% uptake of a DHN, built in two construction phases, anchor loads then full roll out.

Further to this, two sub decarbonisation cases were considered:

- 'Transformational' case to achieve carbon neutral status by 2030
- 'Leading the Way' case which was much more ambitious (towards climate neutral status), but potentially not deliverable by 2030.

To assess and select the most feasible of the scenarios to be recommended and taken forward for techno-economic assessment, a ranking and prioritisation matrix was completed, based on agreed selection criterion, to identify the most suitable solution.

On merit, the second scenario, DHN was selected for further discussion and assessment of possible funding routes to delivering by 2030.

A commercial modelling for Scenario 2 was developed to provide key metrics to a cash flow model (see Section 10). The cash flow modelling allows generation of key indicators including NPV and IRR, while providing key metrics such as the capital cost per tonne of CO2 saved.

As indicated early in this project, the financing aspect is a significant part of the feasibility assessment, and a strength of this project was to bring the commercial discussions early into the feasibility decisions. Ikigai Capital have provided insight into available funding routes and helped to develop a finance and resourcing plan (see Section 11). This has informed how the commercial model for the delivery and management of the CNGCID could be managed and matured in the early project lifecycle stages.

Following completion of the key steps noted above, a route map was constructed to clearly show the steps required to ensure the district meets its carbon reduction goals. This is demonstrated on an Infographic in Section 8.

In support of this study, several Technical Notes have been issued throughout the work on the key themes. These documents provide more detail on the relevant measures, which should be read in alignment with the content of this report (see Reference section for full listing).

2. Climate Neutral Route Map

A route map has been created to provide key facts around how the district shall achieve carbon neutrality by 2030. The purpose is to provide a one-page summary to stakeholders of the whole systems approach to achieving Net Zero Status by 2030. The route map lists out the base measures which help reduce carbon consumption and each of the following sections in this report describes the measures listed below in more detail to demonstrate how the district can meet its targets.

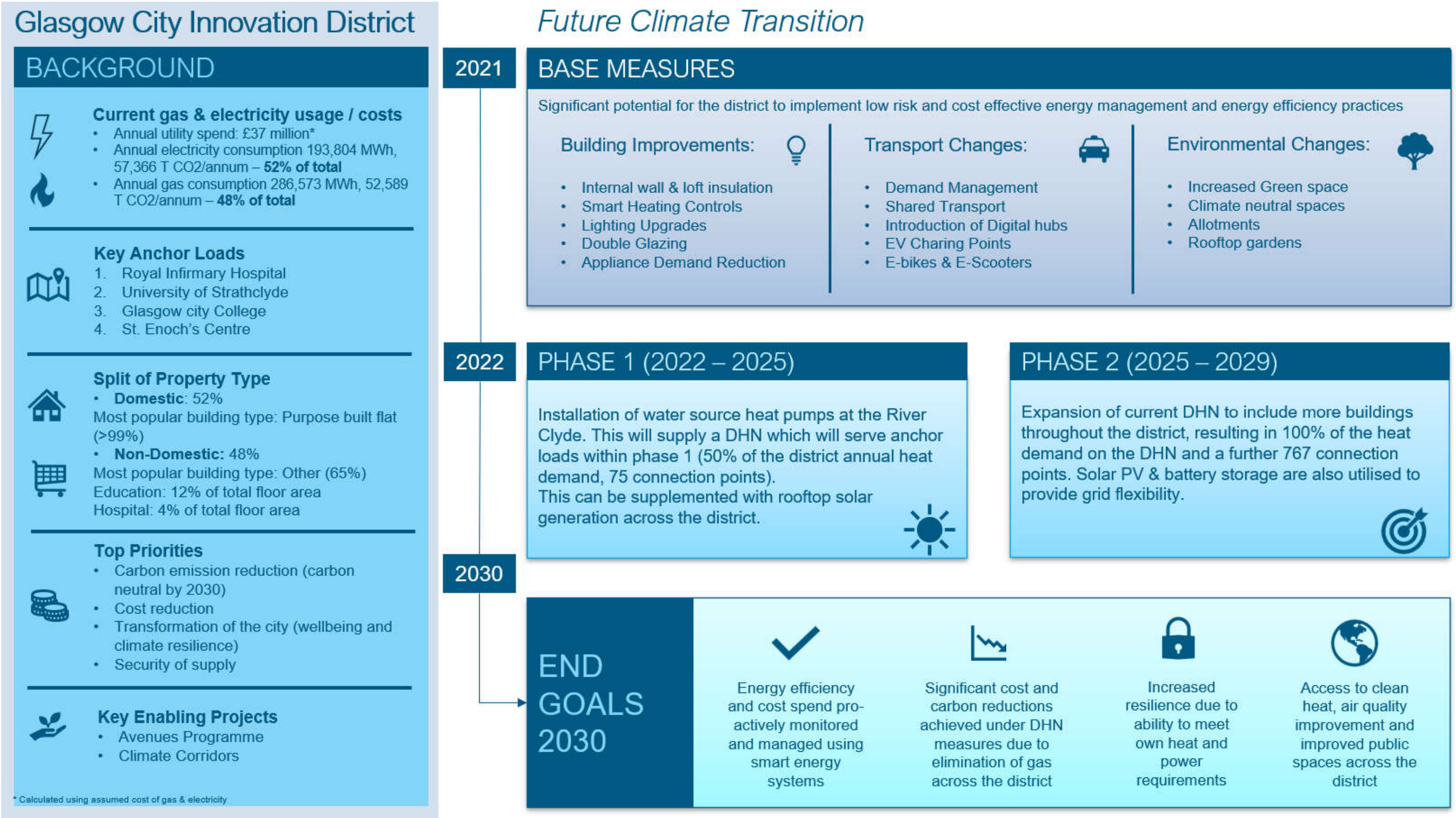


Figure 2-1 - Route Map

3. Building Measures

The technical assessment of building measures was introduced in the workflow in Section 1. This was an iterative process, to refine and select the optimum building measures to offer maximum carbon savings long-term. This work has been closely supported by our partner, the Energy Systems Catapult (ESC), using the industry leading EnergyPlus energy demand modelling. Local Area Energy System Representation (LEAR) is the term given to the model that ESC use to analysis the local energy systems, and understand the potential impact, opportunities and benefits of new smart local energy solutions.

The key assumptions and exclusions are detailed within a Technical Note issued from ESC, titled 'Technical Note to Supplement GIS Datasets'. [5]

Across GCCNID, two different building scenarios to help transform the district to Net Zero were assessed. The first of these demand scenarios,

- **Scenario 1** considered all existing gas boilers being supplied with a 20% volume hydrogen mix and all existing electric resistive heating replaced with air source heat pumps (ASHP). (see section 2.4 for detail)
- **Scenario 2** considered all buildings having a district heating network (DHN) connection, where gas isn't needed for industrial processes. (see section 2.5 for detail)

3.1. Baseline Report (2020)

Building heat demands are the primary use of grid services, accounting for approximately 41% of the total energy demand across the UK. To build an understanding of the energy use within the CNGCID, the study engaged stakeholders for real energy data (where available) to complement the EnergyPlus model, which based demand cases on building archetypes, supported by Energy Performance Certificates (EPC).

To review the complete energy demand case for the district the information was broken in to two main areas: domestic & non-domestic.

The ESC led 'domestic' modelling was summarised in to 10 'archetypes' which grouped homes into different categories based on their floor space, thermal mass and heat loss rate. Data on the energy attributes of the building by type was taken from the Scotland Housing Condition Survey. [5]

The non-domestic modelling was completed by using industry standard benchmarks with the floor areas for each building to determine annual demands. Ordnance survey data was used and supplemented with Energy Performance Certificates where available.

The most popular domestic building type in Glasgow is a purpose build mid floor flat, accounting for 83.2% of all buildings and the majority of buildings are 1965 - present day builds (71%). The largest percentage of non-domestic buildings in Glasgow are 'Other', followed by retail then office buildings. Approximately 99% of domestic properties have no loft due to the large majority being flats, while 68% have cavity filled wall insulation.

Within CNGCID, 93.68% of properties have double glazing, with 65% of dwellings having a gas boiler. The other 35% have electric resistive storage heating. Further detail is provided in the baseline report [1] and ESC technical note [5].

The buildings were assessed to better understand the high energy users, and types of users. For the early optioneering workshops to discuss/agree building measures, these were discussed in the following categories:

- **Hospital**: highest single point load, subsequently highest opportunity that interventions can make large impact on emissions. As a public infrastructure asset, funding (public and private) is at scale and secured against public infrastructure therefore a lower risk investment.
- **University**: A substantial single point load, large opportunity that interventions can make large impact on emissions.
- **City of Glasgow College - Riverside**
- **St Enoch Shopping centre**
- **Non-Domestic**
- **Domestic (Social & private)**

3.2. Energy Efficiency Measures (2030)

To achieve as close to climate neutral status for the 'Transformational case' building fabric measures were considered within the EnergyPlus mode, to improve thermal inertia, heat loss, and thermal comfort. The list of potential measures was shortlisted through sensitivity work, applying each to the majority building types, to determine the impact on carbon emissions.

The building fabric measures were also considered as critical to enabling the future scenarios considered. For instance, Scenario 1, with the inclusion of ASHP, requires a high level of building thermal performance, as the ASHPs deliver a lower temperature heat.

The LEAR 2 measures were then agreed upon and applied to the CNGCID, these include:

- Uninsulated solid walls given internal insulation
- Single glazed windows replaced with double glazing
- Loft insulation of less than 200mm replaced with 200mm+
- Heating controls upgraded to smart controls
- fixed demand for lighting has been reduced by 23.8%
- appliance demand reduced by 19.5%

The future climate/weather was simulated and applied to the modelling to understand the impacts of the measures assumed, and this was done using EnergyPlus weather files created by the University of Exeter. These measures alone resulted in an estimated **energy reduction of 22.3 to 31%** (depending on building type).

3.3. Additionality

Within the LEAR 2 modelling, there is the potential to include additional measures in the modelling assessment. One of these is rooftop solar which can be installed on the available space across the district. After available space, potential shading and aspect have all been considered, an estimated area of 416,214m^2 could be utilised for rooftop solar. As it is unlikely 100% of the useable roof space will be utilised for solar, a utilisation factor of 0.33 has been applied [5] and this corresponds to a **Solar PV generation potential of 24 MWp per year**. The total annual PV generation for the district is estimated at **19.44 GWh per year**. This additional generation capacity could then be used to offset some of the area's electricity demand or could be sold back to the grid depending upon the agreement entered.

Direct Air Capture (DAC) is another option for consideration which could be introduced in a few years' time. This involves using chemical reactions to capture CO_2 directly from the air, by using either liquid solvents or solid sorbents. Due to the temperatures required for each of the types of DAC, it is likely a solid sorbent would be utilised to remove CO_2 from the atmosphere, as this type of system can use lower grade waste heat. It will selectively react with and remove the CO_2 from the air while allowing other components to pass through. *[Note DAC was not included in the forecast or route map as the option is considered a means to reduce residuals and not a core decarbonisation strategy. It is however included in the 'Leading the Way', section 10.]*

3.4. Scenario 1 (20% H_2 in grid & local electrification of heat)

This scenario is based on key flagship hydrogen projects in the Scotland and wider UK. For instance, Project Acorn in Aberdeen and HyNet in NW England. These projects pioneer hydrogen blending into the national transmission system (NTS) first in small amounts (<2%) then up to 20% and with future aspirational cases up to 100% H_2 by volume. These projects have a parallel CCS project, and both streams are strongly supported through BEIS government funding. This is shown through for instance Boris Johnston's 10point plan, where Hydrogen's role as critical to Net Zero was point 2. Also, further support is given in the UK hydrogen strategy, released in August 2021 where 5GW of low carbon hydrogen production are targeted by 2030.

This scenario assumes all current gas boilers are replaced with hydrogen ready boilers, capable of combusting a 20% blend of hydrogen (H_2) and 80% natural gas (NG). In addition, for existing electrically heated properties (e.g. public domestic) the electric restive heaters would be replaced with ASHP.

Despite the 20% blend of clean H_2 in the gas mix, the carbon reduction per unit (kWh) was calculated at **6.56% CO_2 reduction for the hydrogen-NG mix**. The level of decarbonisation only becomes comparable to the volume mix of hydrogen at very high ratios, e.g. above 90% H_2 by Volume. This is due to the very small molecular weight of hydrogen.

By performing LEAR 2 modelling, the energy impact of this scenario across the district could be understood. By assessing the 2030 emissions to the base case scenario (2020), implementation of these measures results in an **overall carbon reduction of ~42% by 2030,** as shown in section 6.

3.5. Scenario 2 (100% DHN)

This scenario considers the installation of a DHN in the area, which will be installed in two construction phases (anchor loads by 2025 and full DHN by

2030). The anchor loads are shown in Appendix D, and the energy demands as follows:

Table 3-1 - Anchor loads split of total heat demand

Anchor load building	Split of annual heat demand consumption
Hospital	30%
University of Strathclyde	11%
Riverside College	1.5%
St Enoch Shopping Centre	7%

The energy centre could be located south of the River Clyde, across the river from Glasgow Green. There is a strong case to site it near the Gorbals energy centre to benefit from the past feasibility work undertaken by STAR. A concept of this plant is given below:

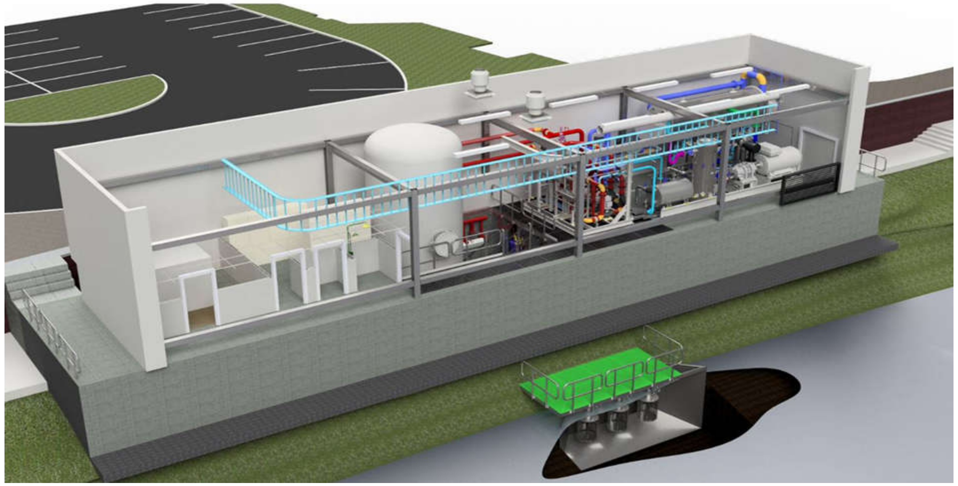


Figure 3-1 **- Concept Image Gorbals WSHP Energy Centre**

DHN design key facts:

- Four water source heat pumps (WSHPs) will be used.
- WSHP will provide ~70 MWth to the area for full DHN, and 25MWth for anchor loads.
- The resultant peak electrical load is approx. 8.3 MW and 23.3 MW for the anchor and 100% DHN phases.
- The WSHP modules would be positioned in the river downstream of the Glasgow Green tidal barrage past the City Union Bridge, spaced up to 100m apart. Seawater heat source is considered more stable seasonally than river, which can vary with heavy rain.
- The electricity required to supply the WSHP annually for phase 1 of this scenario is approx. 26 GWh, for the full load DHN case by 2030, this would increase to 67GWh.
- The flow and return temperatures have been assumed at 75°C and 55°C stainless steel piping.

3.5.1. Wider City DHN Modelling

An optimum ratio for DHN design is 2/3 heat demand from secure, reliable offtakers and 1/3 from more flexible demand (discussed in more detail in Section 10). This means the anchor loads are extremely important to the overall system design and fundability (this is further discussed in Section 11). The anchor loads, considered for phase 1 construction, were identified first by looking at the energy demand data and ranking the buildings. The buildings were then scored (low-med-high) against a list of feasibility factors:

Peak load, Annual Energy demand, Scale of Capex, Investment duration/ security, Investment complexity (e.g. Public / private), Retrofit challenges/limitations, Proximity to Clyde (heat pumps).

The previous work completed as part of the Heat Vision project[3] provided valuable information which helped develop this scenario. COMSOF were able to use the Heat Vision work to perform cost sensitivity checks and wider energy comparisons of rated heat pump values among other aspects.

The proposed phased construction approach has many benefits, and ensures the main artery DHN routings (e.g. High St.) are established to align with the Avenues project. It will be important for a number of anchor loads to be in place to enable infrastructure to be deployed and these 'early adopters' need to be quickly supplemented by others to build a viable heat network. The phasing must also be woven into the existing city infrastructure projects and planning e.g. the expanded scope of a City Deal Avenues Plan that includes DH, digital, power, scalar adaptation solutions. Demonstration through the anchor loads will also engage funders for the second phase construction through demonstration.

Within phase 1 of the DHN roll out, 75 connection points have been identified, primarily connected to the anchor loads within the area. The demand from the anchor loads is 79,214 MWh. Phase 2 of Scenario 2 assumes further expansion by increasing the total number of connection points to 842. The number of WSHP modules required is increased from two to four.

3.5.2. DHN Routing

The DHN routing is of key importance to the DHN deliverability. As part of this study a routing workshop was conducted, held virtually, to discuss and agree the optimum routing. This was agreed to follow the main artery network of the Avenues Project, being High Street. Also, routing was refined to reflect the existing University DHN and pre-designed network expansion points. An extract of routing is given below, but these are provided in Appendix D in more detail.

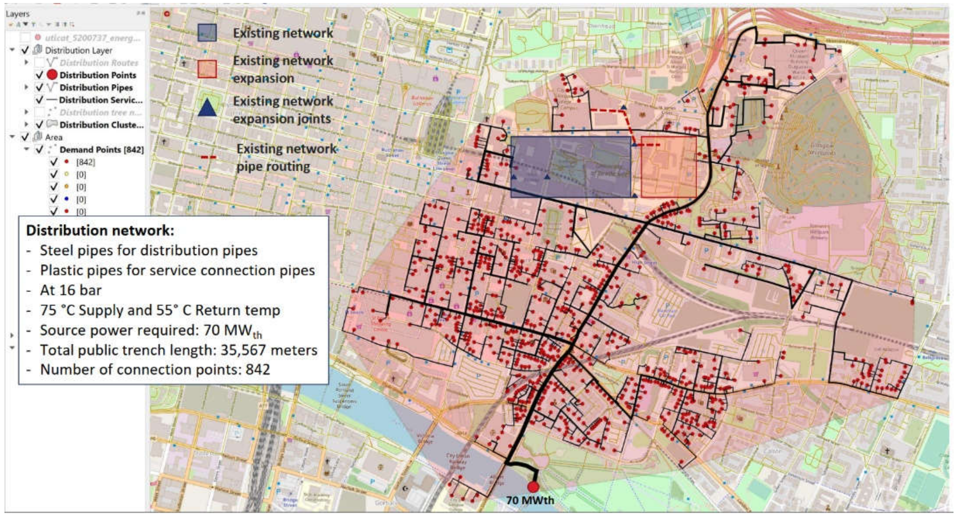


Figure 3-2 - Extract of COMSOF DHN Routing for 100% Network

The routing of the DHN accounts for the existing DHN at the University of Strathclyde and the expansion which is already planned (to the university residence sector and with possible expansion to north social housing).

The cost impact of this is discussed in Section 11.

Installing a WSHP DHN has a significant impact on the carbon emissions of the district. The carbon emissions in 2030 from the 'baseline counterfactual scenario' including growth are 65.7kt CO2e/year, and this is reduced to 18.9kt CO2e/year (for buildings only). This means a **reduction of 71% in carbon emissions** (explored in more detail in section 6).

[3] http://www.heatvision2030.com/assets/files/Heat-Vision2030PaperFINAL.pdf

3.5.3. Seasonal Variation / Flexibility

Several aspects of the DHN design can influence the level of flexibility within the system, and therefore leverage cost or carbon intensity opportunities when importing electricity, as the primary fuel cost. These flexibility measures can offer 'tools' for concepts like the virtual power plant, discussed later in section 6.0. The DHN design flexibility measures include:

1. Seasonal turn down due to reduced thermal demands (as modelled by ESC using EnergyPlus).

	Winter day	Spring day	Summer day	Autumn day
HEAT demand load factor (% hours daily ON)	58%	45%	26%	39%

2. Seasonal turn down by lowering max. flow temperature (e.g. a flex of 5C to a flow temp of 70C delivery, can offer a ~6% electrical saving in summer)
3. Thermal inertia provided by building materials, e.g. concrete floor or stone walls retain heat allowing a level of thermal charging
4. Energy Centre sited heat buffer. Required to provide a level of back up heat storage, but also to smooth the operation of the heat pumps, which prefer baseload type operation.
5. Thermal buffer effect in water heat source. This is twofold, in that the top layer of water is heated by solar, but also a level of freshwater/seawater separation (or stratification) can occur at the Glasgow Green tidal barrage.

3.5.4. DHN Optimisation (Minibems Heat Controller)

To ensure the WSHP on the River Clyde can work consistently throughout the year, it will be optimised to ensure low primary and return temperatures are achieved. This will enable a high average coefficient of performance (COP), by controlling the flow of heat at the point of use by using Minibems approach.

By using optimisation software that monitors the flow rate and flow temperatures at the homes themselves, this can feed back to the energy centre and ultimately influence how the heat pump is controlled. Variable flow temperature control and dynamic return temperature control allow the temperatures of the network to work in alignment with the outside temperature. When the primary network return temperature is maintained, the COP improves, and this reduces the peak load. In one case study, by maintaining a primary network return temperature of 30° C, the average **COP is improved by 23.1%** with the corresponding electricity usage falling by the same percentage. This subsequently reduces the size of heat pump and pipework which is needed, meaning the capital and operational expenditure is also reduced.

This optimisation is achieved by 'Minibems' using a heat controller in each heat network consumer. The controller is typically connected to 6-12 devices within each HIU/ apartment. Software configuration, data analysis, metering and monitoring are all conducted remotely via cloud servers. Metering and billing services are provided using the same controller and valve set.

3.5.5. Additional Heat Sources Considered

When considering the DHN heat source, the Clyde sourced WSHP was the primary solution, however through discussions with the Stakeholder groups, several other opportunities have been identified. Some of these options have already benefited from early feasibility studies. To investigate these options several stakeholder calls were set up and RFI's raised for available info. A summary is provided below. The most credible opportunities here would benefit from further feasibility work when applied to a 100% DHN for the CNGCID.

Table 3-2 - Additional Heat Sources

Heat Source Option	Concept	Summary
Polmadie EfW plant, heat offtake	Taking a heat offtake from the Polmadie Viridor plant, and piping it to the CNGCID.	Although the plant was designed to offtake ~6MWth heat, the (~16MW) electrical output of the plant was maximised and this is now contractually bound. The 6MWth is therefore not available, as it would reduce the electrical peak generation.
Sewer systems	Several desktop studies have been undertaken by Glasgow Caledonian Uni, SHARC, SW Horizons, & Wheatly group.	Up to 4MWth was shown to be possible from a main sewer line below Buchanan Bus station. It's possible that several other sites in city could offer similar. Further investigation/feasibility work is needed within CNGCID.
Sewer outflow, e.g. Dalmarnock		Many of these heat sources are already being explored/utilised by SW.
Deep geothermal, e.g. Hotscot project	DEEP geothermal is linked to old coal seams/mining industry, where access to high temperature water	UKRI has funded research in the central belt of Scotland which should set out a feasibility framework for this option.
Distilleries heat source;		Opportunity is limited based on Distillery requirement for closed loop heating, and higher containment controls due to food/beverage manufacturing.
Ambient temp DHN	Lower temp DHN flow and return with heat upgrade units per building.	Although higher COP are achieved at central heat pump, the overall system energy lifecycle results in lower efficiency. Also requires large pipe bore.

3.6. CO_2 Net Emissions of Building Measures

The combination of building efficiency measures (section 2.2) with the step change Scenario 1 or 2, offers significant carbon savings by 2030. The carbon savings are further improved by the NTS grid intensity dropping from ~156g to 51g/tCO_2/kWh during this period[4]. The impact of this is discussed further in Section 6.

[4] Note that the BEIS issued values were updated in July 2021 to revised values from 138g (2020) to 82g CO2e/kWh (2030) to 156g (2020) to 51g CO2e/kWh (2030). This impact is seen only in the LEAR 2 results.

Table 3-3 - Summary of Heat & Electrical Demand for CNGCID

		LEAR 1 2020	LEAR 2 2030	change	Comment
Scenario 1 - H2 + Local electrification	Heat annual (kWh)	232,124,481	227,506,393	~	nominal change only due to slightly higher boiler efficiency
	Heat annual CO_2 (kgs CO_2/yr)	52,692,257	39,333,820	-25%	reduction due to grid carbon intensity reduction
	Elect annual (kWh)	213,361,373	173,799,358	-19%	Includes ASHP heating (although relatively small number of properties)
	Elect annual CO_2 (kgs CO_2/yr)	29,439,678	8,573,402	-71%	Includes ASHP heating
	Total CO2 remaining	**82.1 ktCO_2/yr**	**~50 ktCO_2/yr**		
Scenario 2 - 100% DHN	Heat annual (kWh)	232,124,481	203,637,718	-12%	Total annual heat demand slightly reduced due to higher DHN system efficiency
	Heat annual CO_2 (kgs CO_2/yr)	52,692,257	3,434,857	-93%	**Significant reduction** due to grid carbon intensity reduction
	Elect annual (kWh)	213,361,373	165,053,776	-23%	Non heat demand (e.g. plug loads, lighting)
	Elect annual CO_2 (kgs CO_2/yr)	29,439,678	8,352,128	-71%	Non heat demand
	Total CO2 remaining	**82.1 ktCO_2/yr**	**11.8 ktCO_2/yr**		

Assumptions:

- WSHP achieves COP of 3.0 at 75C delivery temperature, ASHP achieves COP of 2.0
- Electrical (non heat) demand case taken from Scenario 2 for Scenario 1 (as in this scenario all electrical is non heat).
- Carbon values for LEAR 2 updated using BEIS provided July 2021 values.

3.7. Key Findings; Building Measures

- Building heat demands are a primary use of grid services in the UK (gas and electrical) and therefore major contributor (93%) to the baseline CNGCID carbon case for 2020. A step change approach is needed for heating. A city wide DHN is a very credible means of achieving this.
- The Anchor loads consume 50% of the CNGCID annual heat demand, to 75 buildings. These include the Royal infirmary Hospital, University of Strathclyde, Riverside College, St Enoch Shopping centre
- Improved building energy efficiency to maximum achievable levels of thermal performance is a key enabler to any future 'step change' decarbonisation pathway, such as a city wide DHN scheme. This needs actioned in the immediate term.
- DHN next steps: Glasgow City Council must approach how they will de-risk a project of significant infrastructure scale by appointing a task force to establish the appropriate legal structure of an organisation to manage the project technically and commercially.

4. CNGCID Social Value Plan

4.1. Approach and Methodology

Atkins has defined an approach to embedding social value into the development of the CNGCID. This is intended as a preliminary review; more data and insight are needed to develop this approach into a robust plan. Information is included on policy relating to social value, data to inform understanding of key issues and guidance created by key players in the social value space such as UKGBC and ICE as well as recommendations based on Atkins' own experience.

Introduction

This piece of work provides a real opportunity to provide added social value to the communities connected to the CNGCID. Understanding the impacts of decisions made through the planning, design, development, installation and operation of the set of proposed interventions is key to unlocking social impact.

Questions need to be asked every step of the way, such as:

How can local skills be best used to support this?	How can we upskill local people to support this and future work?
How can we work with stakeholders to co-design?	How can we ensure opportunities created are accessible to all?
How can we design with circular economy in mind?	How can we work with SMEs, Third Sector Organisations (TSO's) and other local busines?'
	How can services take into account the needs of the local community?

This image is taken from 'UKGBC Framework for Defining Social Value'. It provides the context for the recommendations, highlighting the areas social value permeates. It is important to recognise the impact connected to CNGCID on the very local community, through the supply chain, the Glasgow City region and how this addresses the challenges faced on a global scale.

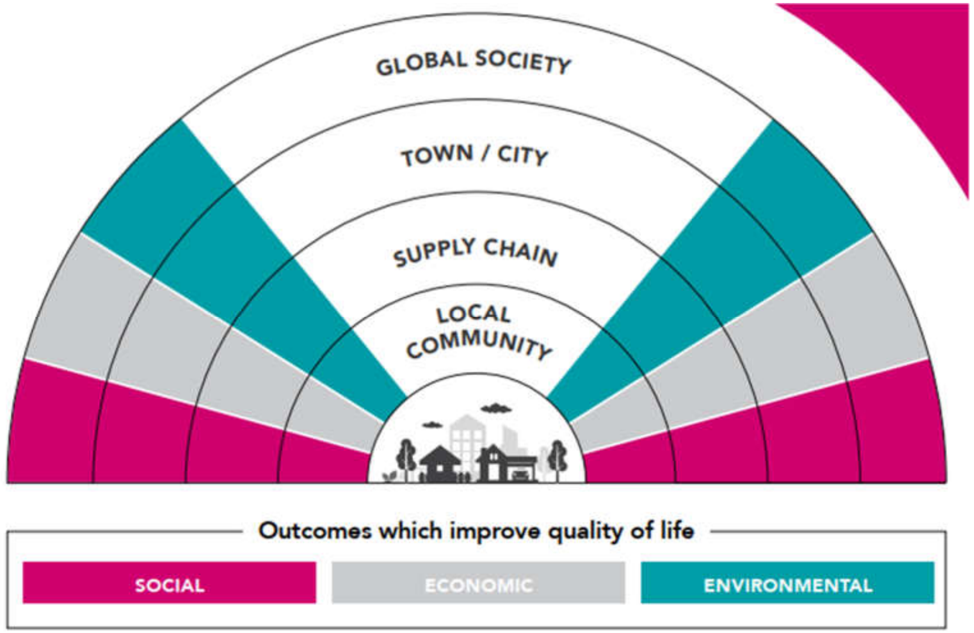


Figure 4-1 - Definition of Social Value for the Built Environment

Policy Context

Policy around social value is a key driver for governments in Scotland and UK. Policy has evolved in recent years and now plays a key role in public procurement. Policy which relates to this piece of work include:

- Procurement Reform (Scotland) Act 2014
- Scottish Policy Procurement Note 10/20 (SPPN 10/20)
- Social Value Act 2012
- Construction Playbook

SPPN 10/20 key messages - the Scottish government does not endorse monetary gauges to measure social impact. Public bodies must engage with communities who have an interest in the contract to get best possible outcomes; impact measurements should not create a barrier to businesses; success is measured in terms of outcomes aligned to the National Performance Framework and the UN SDGs. The approach complements procurement principles to rule out price or cost only as the sole award criteria for public contracts.

The Construction Playbook focusses on value-based procurement rather than the Most Economically Advantageous Tender (MEAT).

Other Key Drivers

Community Wealth Building

Community wealth building (CWB) is a people-centred approach to local economic development, which redirects wealth back into the local economy, and places control and benefits into the hands of local people. CWB aims to ensure the economic system builds wealth and prosperity for everyone.

There are five core principles to CWB:

1. Progressive procurement
2. Fair employment and just labour markets
3. Shared ownership of the local economy
4. Socially just use of land
5. Making financial power work for local places.

Anchor organisations are large employers with a strong local presence in an area. They can exert sizable influence through their commissioning and purchasing of goods and services, through their workforce and employment capacity, and by creative use of their facilities and land assets. Positive use of these aspects can affect social, economic and environmental change in an area. Anchors can be your local council, university, college, housing association, NHS health board or large local private sector employer.

CWB in Scotland

The Scottish Government is committed to exploring the potential for CWB as an approach to delivering inclusive growth across Scotland, with six key projects in development across a range of contexts in Scotland including the Glasgow City Region.

Scotland's National Performance Network

This defines 'Our Purpose, Values and National Outcomes' and sets them in context of National Indicators and Sustainable Development Goals.[5]

University of Strathclyde

The University's own Climate Change and Social responsibility Plan is also a main driver to this work and aspect.[6]

4.2. Delivering Social Value

Local Context

Understanding the needs of this and wider local communities and connecting with stakeholders will help to ensure that local people are involved throughout. This will allow decisions to be made which will shape the future of this area with the needs of people and the environment at its core.

The district region contains pockets of areas with high levels of deprivation, is currently lacking in green space - green walls, roofs or SuDS, etc (although there is access to green space locally). The 'Avenues' initiative is planned to protect space for pedestrians, cyclists, improve connectivity, introduce sustainable green infrastructure, through attractive streetscapes and enhancing biodiversity. Glasgow City Centre Living Strategy proposes a route to doubling the area's population size to 40,000 over the next 15 years.

---

[5] NPF_A4_Booklet.pdf (nationalperformance.gov.scot)

[6] https://www.strath.ac.uk/media/ps/estatesmanagement/sustainability/sustainabilitytemp/SD_and_Climate_Change_Policy.pdf

https://www.strath.ac.uk/professionalservices/media/ps/estatesmanagement/sustainability/sustdocuments/SDGs_in_Strathclyde's_CCSR_Plan.pdf

https://www.strath.ac.uk/media/ps/purchasing/procurementmanual/Socio_Economic_Impact_and_Community_Benefits_Strategy_200318.pdf

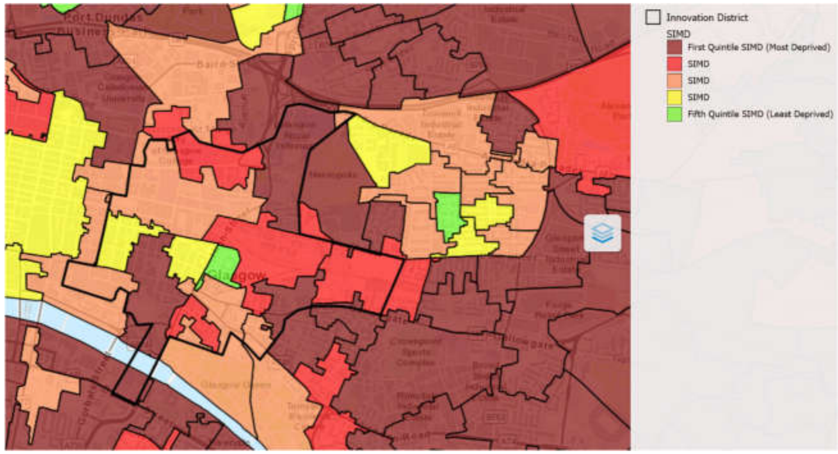


Figure 4-2 - Distribution of Scottish Indices of Multiple Deprivation in the CNGCID and Environs

Stakeholder Engagement

Identifying stakeholders and defining how they can be involved in co-design, planning, delivery and ongoing upkeep from the earliest moment is key to success. The primary beneficiaries of social value should be those most impacted by an action or intervention. Stakeholder groups can be defined by geography, employers, residents, property owners, residents, workers, visitors and charity and community organisations.

The ‘UKGBC Framework for Defining Social Value’ provides a mapping exercise for identifying stakeholders by lifecycle stage and asset type. A process of this type could be used to identify stakeholders:

- Gathering evidence of stakeholders impacted by similar project
- Consulting relevant local authority documentation such as Area Action Plans
- Engaging with visible community stakeholders and groups e.g. Residents Associations, local service providers, community and faith groups, local charities
- Consulting with people interacting with the asset
- Consulting the building use data of existing buildings

Additional recommendations:

- Undertake stakeholder mapping to identify what their influence on the local community is and who they represent, their individual aims for the project and how they link together
- Produce a Social Value Plan on how social value can be embedded at each stage of the project lifecycle
- Obtain feedback from stakeholders to measure effectiveness of social value being delivered
- Identify the preferred ways of communicating with stakeholders (particularly local residents, interest groups and social enterprises)
- Work with third sector organisations who support hard to reach groups to identify ways of working effectively together during delivery
- Work with other initiatives e.g. The Avenues to align with stakeholders across multiple schemes
- Establish a steering group made up of key stakeholders (including anchor institutions)

Scotland’s Place Standard aims to help users to understand the existing and potential strengths of a place and inform decisions which allow for targeted resource where they are needed the most. It can help to support the design and delivery of successful places creating good quality development where people want to live.

Opportunities to Tackle Social and Economic Inequality

Potential ways to maximise opportunities:

- Produce a Social Value Strategy that identifies clear and ambitious outcomes relating to creating employment opportunities and new businesses and providing training for the local workforce – identify trades needed to carry out design, installation and maintenance. Do these trades exist locally? Can other trades be re-skilled or upskilled? Review the supply chain to understand what local manufacturing facilities exist to support and identify opportunities to adapt and upskill locally.

- Assess priorities around employment opportunities, providing education and training programmes through hosting workshops from the earliest opportunity.
- Analyse employment and training needs of the local community/ area via stakeholder engagement and desk-based study – match the employment and training needs with the opportunities to design, install and maintain.
- Find ways to access harder-to-reach groups (e.g. prison leavers, care leavers) for example through training provision in prisons
- Set up an effective reporting system to measure the effectiveness of employment and training opportunities being delivered.
- Partner with local educational institutions to train disadvantaged local people into skilled professions – think about green skills and future employment opportunities.
- Link with education to inspire the next generation to have pride in their local area and want to be involved in its development, helping young people to make the connection with jobs created for the short and long term through the heating system and other initiatives.

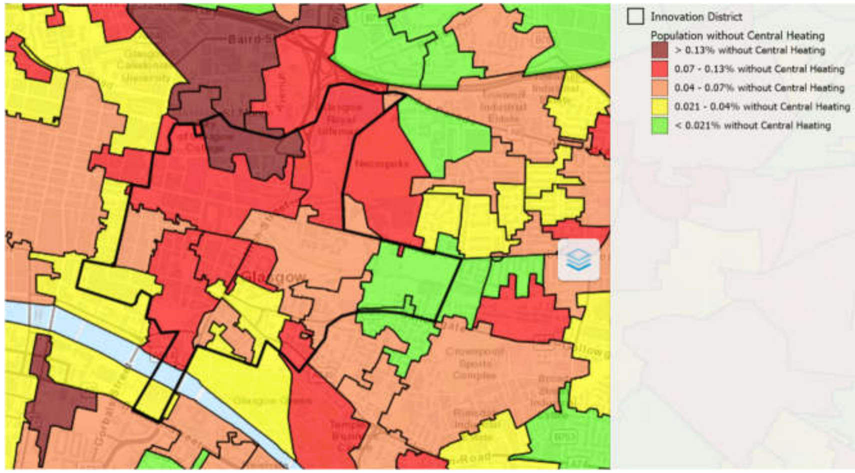


Figure 4-3 - Distribution of Population with Central Heating in Central Glasgow

The following are key considerations:

- What can be done to ensure a wide range of organisations benefit from potential opportunities?
- Recognise the benefits of working with a wide range of suppliers including TSOs (Third Sector Organisations), SMEs and entrepreneurs - provide opportunities for such organisations to access the supply chain.
- Provide training, mentoring and support for organisations through existing bodies such as Supply Chain Sustainability School.
- Identify and partner with TSO's/ job centres/ local authority/ charities /local schools to create a network that can create access to opportunities for people from hard to reach groups.

Undertake delivery model assessments to make them more attractive to SME's (breaking contracts into smaller, simplified lots, reviewing contract lengths and risk allocation).

Opportunities to Improve Wellbeing Through Environmental Factors

Air quality management – an AQMA covers a large part of the CNGCID. The interventions proposed for the CNGCID are expected to result in outcomes of lower air pollution overall and especially in pedestrian zones.

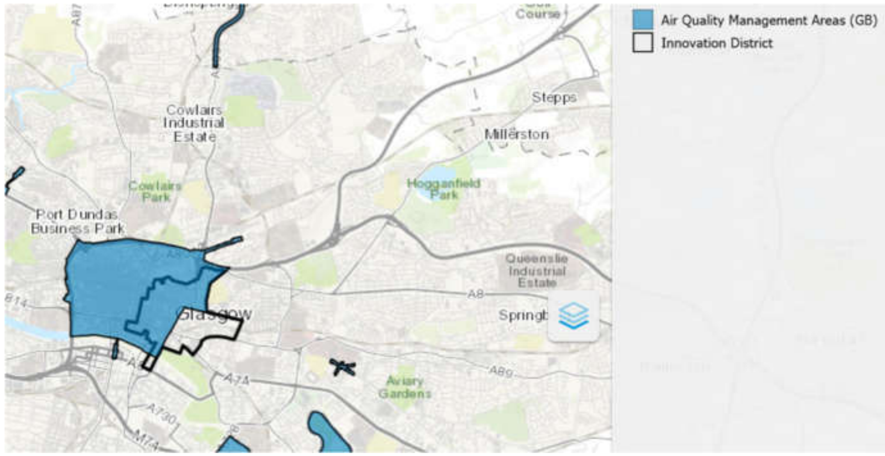


Figure 4-4 - AQMAs in Central Glasgow

Biodiversity – improved biodiversity from proposed interventions can provide better wellbeing for people using the area. How can the installation of the system maximise opportunities for this?

Consider the impact the proposed energy system interventions will have on aspects such as:

- Fuel/energy prices – how will these change and how will these impact people positively or negatively?
- Fuel poverty – will the changes provide the opportunity for people living in fuel poverty to rise out of this?
- Will the system have an impact on EPC ratings?
- What will the impacts be on thermal comfort – physically and on mental health and wellbeing? How will these impacts be measured?

A small number of buildings within the district do not have central heating. How can the proposed interventions support improved standards of living for these residents without adding financial burdens?

4.3. Conclusions and Recommendations

Development of the CNGCID provides some real opportunity to add value to local communities through a wide range of impacts including employment, skills, education, wellbeing, biodiversity and economic equality. It is recommended that steps are taken to engage with stakeholders from across the community at the earliest opportunity to begin to define their needs and understand how the programme can support these. Further work is needed to determine who stakeholders are, particularly within the areas of the highest deprivation.

Taking forward the set of proposed interventions will require existing and new skills – understanding what this means in greater detail is an important next step in order to define employment opportunities and to allow educators, training providers and employers to prepare themselves to support. [7]

Policy and other drivers surrounding social value have a spotlight on them, meaning there is a great opportunity to access best practise, advice, guidance and peer support from a wide range of sources to inform next steps.

This piece of work can be taken forward in more detail to further explore the impact on social value, the metrics which can be used to substantiate proposed interventions and to capture potential impacts.

[7] Further information on these areas can be reached through the following links:

- Measuring social impact in public procurement: SPPN 10/2020 - gov.scot (www.gov.scot).
- UK Social Value Act 2012 - Social Value Act: information and resources - GOV.UK (www.gov.uk).
- UK Construction Playbook - The Construction Playbook - GOV.UK (www.gov.uk).
- Community Wealth Building Case Studies - Scotland's Centre for Regional Inclusive Growth
- UKGBC Framework for Defining Social Value Framework for Defining Social Value - UKGBC - UK Green Building Council.

5. Environment

To help achieve carbon neutrality within the district, the environment plays an important part in reducing carbon emissions. Climate resilience, green infrastructure, climate neutral spaces and climate corridors are all environmental considerations applicable to the district. These, among many others, are explained in more detail within the following sections.

5.1. Carbon Efficient and Climate Resilient Environmental Improvement

A review of existing studies and other baseline information relating to climate change adaptation was undertaken to understand the CNGCID's vulnerability and exposure to the future climate case. The review included analyses of underlying natural features of the CNGCID and its immediate environs as well as the urban morphology of the District. This is presented in the technical memo (5200737-EN-MEM-002 Climate Risk Assessment and Environmental Improvement Tech Note) [7].

The results of the review indicated that there is considerable potential for developing a highly effective urban environmental improvement programme for the CNGCID, based on a **"climate corridors"** concept centred on the multi-function, multi-benefit features of green infrastructure.

Overall key recommendations from the review are:

- The risk of increased flooding, both river and surface flooding, urgently needs to be addressed with a strongly **climate sensitive approach to urban environmental improvements**.
- There is a need for a climate responsive approach to urban environmental improvement which **balances the need for protection** from climatic extremes in the long winter, **with optimising benefits** from favourable conditions in the short summer.
- The urban environmental improvement programme should be informed by analysis of **proven best practice** to enable optimal contribution to the aims and objectives of the CNGCID.
- There are indications that there is scope for **enhancing the planned interventions** with a more fully integrated sustainable outcomes led approach across all key sectors.
- Although **estimated carbon removals** from existing vegetation cover represent a small proportion of estimated current emissions, the **strong potential to increase vegetation cover** represents an increasingly important means of achieving carbon neutrality within the CNGCID. There are several additional indirect benefits also, including improved city image, tourism, and improved health and wellbeing.

The review of the districts potential for developing an urban environmental improvement programme is set out in more detail in the following sections.

- Climate change risk (section 3.2.1)
- Climate Responsive Approach (section 3.2.2)
- Climate Corridors (section 3.2.3)
- Carbon Sequestration (section 3.2.4)

Appendix A includes a selection of best practice ('Green, Car Free City Centres' examples. This includes images and narrative of how changes have been made in other cities and the positive long-term effect. The review includes London, Frankfurt (GER), Copenhagen (DEN) and Ghent (Be) examples.

5.1.1. Climate Change Risk

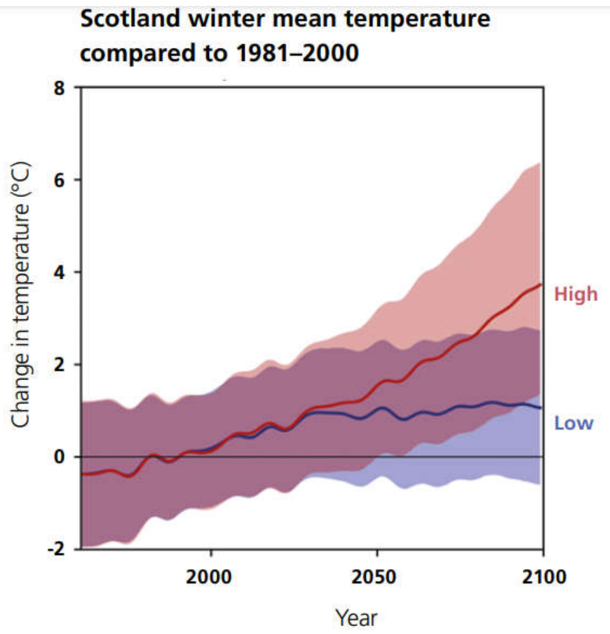
From climate change projections under all scenarios, Glasgow is likely to experience:

- An increase in winter rainfall and decrease in summer rainfall.
- An increase in extreme weather events, including storms, and heavy precipitation.
- An increase in heatwaves and very hot days and nights compared to the baseline climate.
- Increased risk of flooding, both surface flooding and river flooding, with the return period for large flood events likely to decrease.

Analysis by Adaptation Scotland[8] provides a clear picture of projected overall trends in means and extremes of temperature and rainfall for Scotland, summer and winter, as summarised in the figures below.

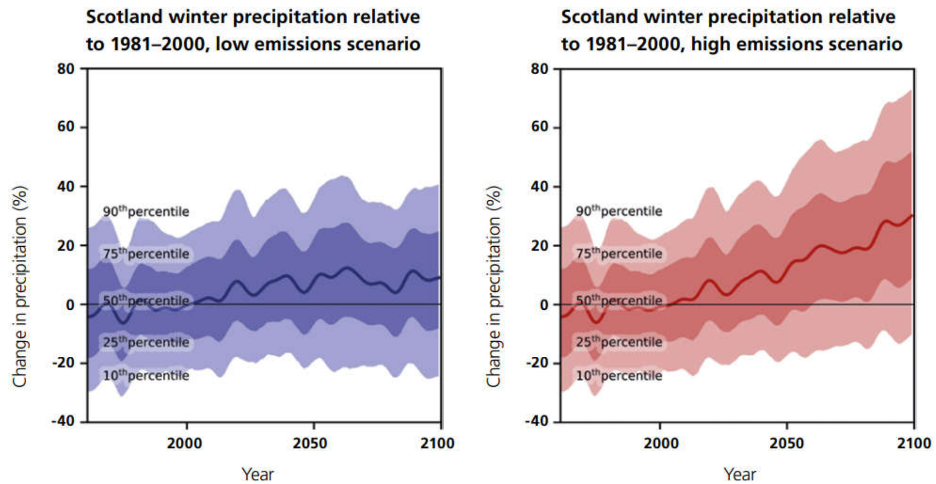
Predicted changes in winter rainfall are of particular concern for the CNGCID in where historically surface flooding is an issue. Predicted changes in summer average and extreme temperature levels, together with substantial declines in rainfall, are likely to have significant implications for a) potential need for building cooling in some months; b) more comfortable outdoor thermal conditions, making the outdoor environment more attractive for a range of leisure and recreational as well as work related activities.

Climate Change Predictions - Winter



Change in winter temperature (°C)

2050		2080	
Low Emission	High Emission	Low Emission	High Emission
1.0°C -0.5°C ↔ 2.5°C	1.5°C 0.0°C ↔ 3.2°C	1.1°C -0.5°C ↔ 2.7°C	2.7°C 0.6°C ↔ 4.9°C

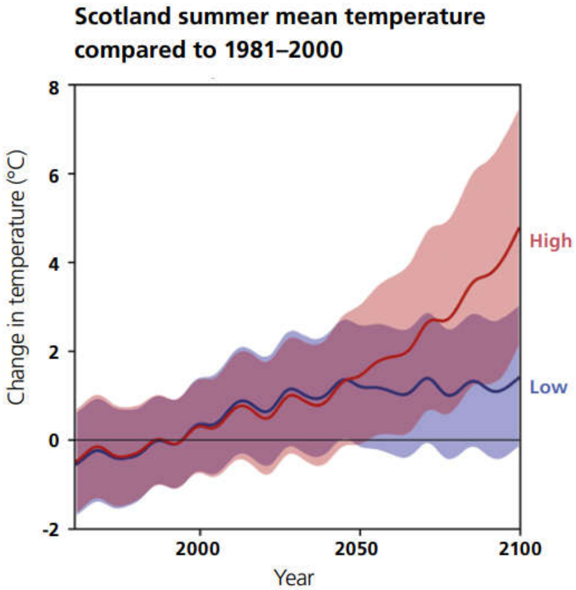


Change in winter rainfall (%)

2050		2080	
Low Emission	High Emission	Low Emission	High Emission
8% -19% ↔ 36%	12% -17% ↔ 42%	5% -24% ↔ 33%	19% -14% ↔ 56%

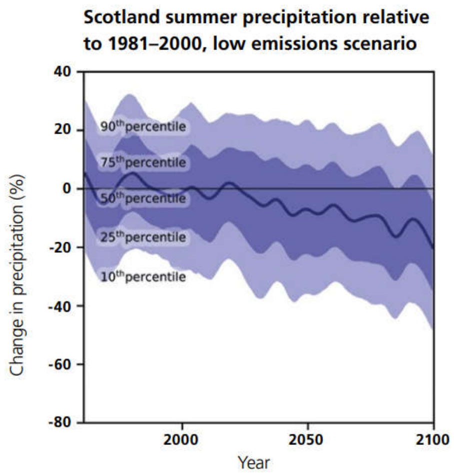
8 https://www.adaptationscotland.org.uk/why-adapt/climate-trends-and-projections.

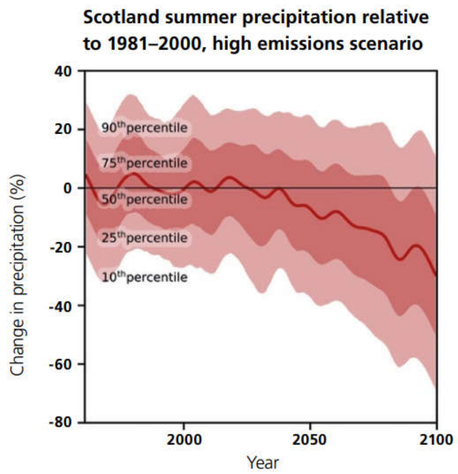
Climate Change Predictions - Summer



Change in summer temperature (°C)

2050		2080	
Low Emission	High Emission	Low Emission	High Emission
1.2°C -0.2°C ↔ 2.6°C	1.5°C -0.1°C ↔ 3.1°C	1.1°C -0.4°C ↔ 2.6°C	3.0°C 0.8°C ↔ 5.3°C





Change in summer rainfall (%)

2050		2080	
Low Emission	High Emission	Low Emission	High Emission
-7% -36% ↔ 23%	-8% -38% ↔ 24%	-11% -40% ↔ 21%	-18% -54% ↔ 21%

Climate Ready Clyde[9] has identified the following key risks for the Glasgow region, which are relevant to the CNGCID, as needing more action or requiring building of capacity and understanding:

Infrastructure

- Risks to energy, transport and ICT infrastructure from storms and high waves.
- Risks to energy, transport and ICT infrastructure from extreme heat.
- Risks of cascading failures from interdependent infrastructure networks.

[9] Climate Risks and Opportunities for Glasgow City Region, Climate Ready Clyde, December 2018. https://www.crc-assessment.org.uk/.

Built environment

- Risks to building fabric from moisture, wind, storms and driving rain.
- Risks to traditional and historic buildings from moisture, wind and driving rain.
- Increased maintenance of green space due to rising temperatures and extreme weather.
- Increased cooling demand in buildings as a result of rising temperatures.
- Risk of overheating of buildings from higher temperatures and heatwaves.

Society and human health

- Risks to people and communities from flooding and flood disadvantage.
- Increase in summer temperatures and heatwaves leading to increased morbidity and mortality.
- Risks to NHS estates due to flooding and overheating.

Natural environment and natural assets

- Risks to soil stock from changes in temperature and water regime.
- Risks to soils from pests, pathogens and invasive species.

Economy, business and industry

- Risk to new and existing business sites from river, surface water and coastal flooding.
- Risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments.
- Risks to business from disruption to supply chains and distribution networks.

The Climate Ready Clyde report also identifies a number of opportunities, some of which are linked to successful adaptation to the identified risks, such as increased tourism revenues from increased tourism, as well as risks associated with cross-cutting and adaptive capacity issues, such as:

- Failure to position adaptation as a strategic economic and social issue.

These findings have clear implications for the CNGCID, both in terms of renovation / design, operation and maintenance of transport and utility infrastructure as well as public realm, streetscape and green infrastructure provision. The latter aspects are explored further in the sections immediately below.

5.1.2. Climate Responsive Approach

The effects of climate change are now already well established and appear set to rapidly increase over the next decade and more, even with implementation of extensive carbon mitigation interventions. In Glasgow, the need to introduce measures to protect from the increasing extremes of temperature and precipitation, especially when combined with strong winds and low daylight in the long winter, is now a strong imperative. Implementation of these measures will need to be balanced with optimising benefits from higher temperatures, daylight and solar energy in the relatively short summer.

Measures such as increasing tree cover with seasonal foliage, and integrating this and other vegetation with surface drainage channels as part of Sustainable Drainage Systems, can be designed to incorporate this optimal balance as ‘built-in. More engineered measures, such as shading structures which can be reconfigured for seasonal change, and hard surfacing designed with solar reflectance properties which optimise year-round thermal performance, can then be incorporated to further enhance overall performance. Outdoor thermal comfort, which is primarily influenced by ambient temperature, humidity and air flow, is a key performance metric. Reducing thermal extremes and humidity, such as via carefully selected vegetation species and providing for moderation of air flow through configuration of urban environment, will form a critical aspect of successful urban environmental improvements. Almost a ‘by product’ of enhancing outdoor thermal comfort is reduction of Urban Heat Island (UHI) effects. Studies have shown quite remarkable differences in UHI effects between urban environments designed for outdoor thermal comfort, particularly with substantial tree cover.

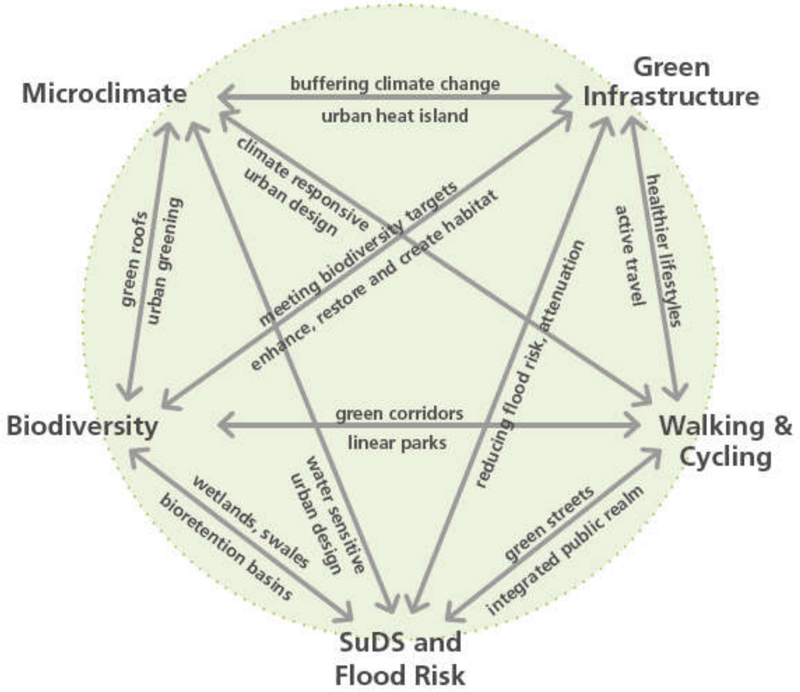


Figure 5-1 - Integrated approach to urban environmental improvements

Source: [Environmental Target Setting Study, Old Oak and Park Royal Development Corporation, 2017](#).

Multi-function, multi-benefit green infrastructure

Introducing and enhancing vegetation cover, particularly carefully selected tree cover, in urban environments has a wide range of benefits beyond enhancing outdoor thermal comfort and reducing UHI effects. These are summarised below:

- **Drainage / Flood Risk** – nature-based solutions to drainage, incorporating Sustainable Drainage Systems (SuDS) approaches and principles, can play an important role in overall climate change adaptation, in terms of stormwater run-off attenuation, reducing flow extremes and fluctuations. Often simple 'grey to green' measures, such as de-paving or reducing / replacing hard surfacing and enhancing non-hard surfaced areas with varied vegetation, can have significant immediate benefits. SuDS can also help improve water quality through vegetation-based filtering of flowing water.
- **Ecology / Biodiversity** – Enhancing the overall extent as well as range and type of vegetation cover, with particular attention to appropriate species selection, ecosystem characteristics and soil and drainage linkages, can result in immediate and rapid benefits to local biodiversity and overall ecological health as well as several 'secondary' benefits, such as health and well-being. A good mix of types of vegetation, including large crown trees and large shrubs, organised as a linked network rather than separated areas, provides immediate habitat benefit to a range of terrestrial fauna as well as birds and insects.
- **Pollution** – air, noise and light pollution can be ameliorated via positioning of vegetation, particularly large crown and / or closely spaced trees. Such vegetation can act as noise and light barriers as well as functioning to absorb and helping to disperse ambient air pollutants.
- **Mobility** – Studies[10] have shown that green infrastructure provision is attractive to NMUs and encourage walking and cycling. Such provision can be incorporated in a variety of streetscape settings, from tree covered cycle / walking lanes to fully separated 'green' routes, as integrated networks.
- **Outdoor Comfort** – Vegetation cover, in particular large crown trees, in the urban environment can provide shading, increased humidity and reduced UHI in summer; shelter from precipitation, moderating air flow / wind in winter. These effects are typically more pronounced in higher density urban environments, where UHI levels are higher and local microclimatic conditions can vary.
- **Carbon / Energy** – large, well established vegetation cover can sequester significant amounts of carbon. By also helping to lower UHI and provide, in the case of green / brown roofs and green walls, insulation, urban

---

[10] For example: https://www.researchgate.net/publication/334304633_The_influence_of_green_streets_on_cycling_behavior_in_European_cities.

vegetation can have substantial effects in reducing thermal building energy consumption (heating in winter and cooling summer). Energy generation provision such as solar panels, can also be effectively combined with vegetation in a variety of integrated public realm settings, particularly green roofs.

- **Place Making**- well designed and implemented green infrastructure forms an essential component in overall place-making, key to creating a sense of pace and supporting social cohesion. The traditional approach of landscape and public realm planning / design and creation of parks and greenspace primarily as amenity is being replaced with a more integrated approach considering ecological integrity, biodiversity, outdoor comfort and mobility as well as overall amenity.
- **Health / Well-Being / Amenity** – Studies[11] have provided increasing evidence for the beneficial effects of green infrastructure and greenery generally on health and well-being, both in non-work and work settings, and in areas such as education and healthcare where access to, and even views of, greenspace appear to have health and well-being benefits. Green infrastructure provision encourages outdoor activities, with clear health well-being benefits linked to recreation, leisure and sport.
- **Urban Farming** – use of green space and green infrastructure more generally for various forms of urban farming, particularly when combined with other benefits such as building insulation and drainage attention from green roofs, is increasingly being recognised as further beneficial effect from (edible) green infrastructure[12].
- **Economic Benefits** – The direct and indirect economic benefits of provision of green infrastructure are increasingly recognised, including effects on property values, attracting workers and investment, as well as in aspects such as worker productivity and job satisfaction[13].

Figure 5-2 - Green wall vs conventional wall, Central London

Thermal image showing the surface temperature of a green wall, central London.
Source: Living roofs and walls: from policy to practice.

The climate responsive, multi-function, multi-benefit green infrastructure centred approach summarised above is closely aligned with existing local strategies and plans: Glasgow and Clyde Valley (GCV) Green Network Strategy for Glasgow City Region[14]; the Metropolitan Glasgow Strategic Drainage Partnership Surface Water Management Masterplan[15]; and the Climate Ready Clyde Glasgow City Region Climate Adaptation Strategy[16].

[11] Examples include:
https://www.forestresearch.gov.uk/documents/2515/urgp_benefits_of_green_infrastructure.pdf;
https://www.greenflagaward.org/news/green-space-improves-academic-performance/;
https://www.commercialrealestate.com.au/news/green-spaces-produce-healthy-workers-834064/
[12] https://cities-today.com/nordic-cities-seek-green-infrastructure-and-sustainable-food-solutions/.
[13] https://www.reuters.com/article/us-health-psychology-office-plants-idUKKCN0HR2DW20141002.
[14] https://www.gcvgreennetwork.gov.uk/green-network-strategy
[15] https://www.mgsdp.org/CHttpHandler.ashx?id=38023&p=0
[16] http://climatereadyclyde.org.uk/gcr-adaptation-strategy-and-action-plan/

Figure 5-3 - Biosolar roof, Clapham Park, Lambeth, London

Figure 5-4 - Urban food growing. Basinghall Avenue, Central London

Mobility

A fundamental component of developing the CNGCID is decarbonising urban mobility. As set out in the Transport section below and the Transport Measures Technical Note [8], the three main means of pursuing this are reducing demand, modal shift and decarbonising vehicle fleets. Urban environmental improvements have a particularly important role to play in the second of these types of measure. Prioritising NMUs, coordinated with improving public transport and reducing parking provision are all supported by, and support, urban environmental improvements. This includes enhancing the range of types of public transport, including taxis. To ensure effectiveness, such mobility interventions should be closely linked with public realm, streetscape, and green infrastructure interventions. As with examples cited above, the eventual aim of the CNGCID mobility interventions should be to move to a car-free area in the city centre. This will need to be done in a carefully planned, closely coordinated phased and integrated approach.

Streetscape and Public Realm

Transformation of the streetscape and public realm within the CNGCID via a programme of phased urban environmental improvements should be centred on a people focused approach, promoting slower movement, increased footfall, more outdoor activity, and enhancing active frontages across the commercial areas of the District: a ‘streets for people’ approach, closely aligned with the existing ‘Places for Everyone’ and ‘Core Paths Plan’ initiatives in central Glasgow.

Integrated Utility Infrastructure

Roads and streets are not just for mobility. They are usually also the veins and arteries through which flow the city’s wet and dry utilities, both over ground and underground. As the main location for much of the city’s hardscaped land, they are also the focus for many of the issues associated with surface drainage: localised surface flooding and sewer overflow. The streetscape is likely to be the key ‘battleground’ for driving city climate change resilience over the next decades. Transforming roads and streets to realise the full benefits of carbon efficient and climate resilient urban environmental improvements will require strong and proactive coordination between infrastructure planners and designers over multi-year programmes, with extensive and continuous monitoring of implementation to ensure not only realisation of intended environmentally sustainable outcomes but also minimal disruption to the social and economic activity of the city and optimal socio-economic beneficial outcomes overall. Recent survey work as part of the 'Avenues' programme (see figure below) has indicated the complex existing infrastructure provision within central Glasgow which will need close attention to ensure successful delivery of the urban environmental improvements envisaged within the CNGCID.

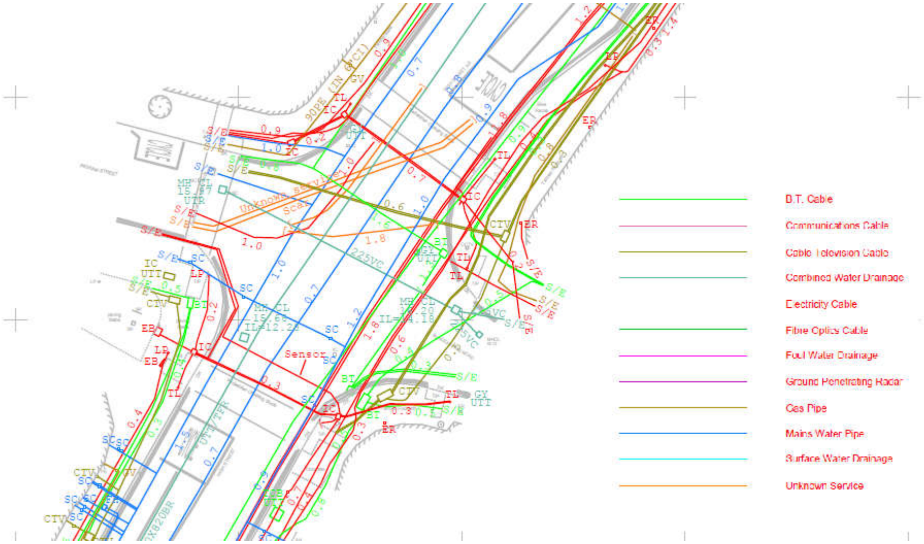


Figure 5-5 - Section of High St. utility provision, Aird Geomatics

Experience in Other UK Cities

Appendix B highlights the experience of other UK cities in developing carbon efficient and climate resilient urban environmental improvements. This review gives examples from Plymouth, Leeds & Manchester.

5.1.3. Climate Corridors – Bringing it All Together

The concept of climate corridors is at the core of the recommended, highly integrated programme of effective urban environmental improvements for CNGCID which optimises benefits across multiple aspects.

As highlighted above, this will require careful planning and design to ensure a comprehensive all-season approach can fully realise such benefits. This will be guided by the underlying natural features (topography, soils, drainage, microclimate) while being sensitive to the different contextual aspects of the predominant urban morphology of the District's various sub-areas. The programme should also be informed by analysis of proven best practice to enable optimal contribution to the aims and objectives of the CNGCID.

Enhancing Planned Interventions

There is a strong opportunity to enhance and expand the planned interventions under the existing Avenues initiative in the city centre to fully embrace the concept of climate corridors, coordinating with works envisaged for the proposed low carbon district heating network (DHN) and mobility initiatives set out in other sections of this report.

Figure 5-6 shows the key components of the proposed low carbon DHN and the relationship between this and the currently planned Avenues routes within the CNGCID area. Although there is considerable overlap, particularly in the western part of the CNGCID and the full length of George Street, there is one clear 'gap': High Street. High Street was originally planned to be included within the Avenues initiative but does not form part of the current programme of work. It represents a major integrating north-south 'spine' route within the CNGCID and is critical for the proposed DHN as it links the early 'anchor load' locations in the north west and north of the District with the low carbon DHN plant proposed on the north bank of the Clyde in the south west of Glasgow Green. High Street is also a key arterial route for current motorised road traffic circulation in the District.

A preliminary analysis of confluence between the proposed DHN and the existing Avenues routes has been conducted to identify potential climate corridor routes. These are also shown in Figure 5-6. The central concepts underlying this analysis were to:

a) firstly focus on confluence of current proposed Avenues routes and proposed DHN routes;
b) identify key components of the proposed DHN not covered by currently planned Avenues routes which also comprised mobility routes with motorised vehicle congestion issues;
c) identify other proposed DHN routes where introduction of climate corridor interventions may be anticipated to provide either catalysing transformative effects in the immediate local area, and / or provide strong synergies with planned new development.

It was also considered important to ensure overall coherence in provision of climate corridors as:

a) an integrated network, particularly in terms of circulation for bicycles but also for pedestrians; and
b) closely aligned with an overall vision for transforming sense of place and local identity.

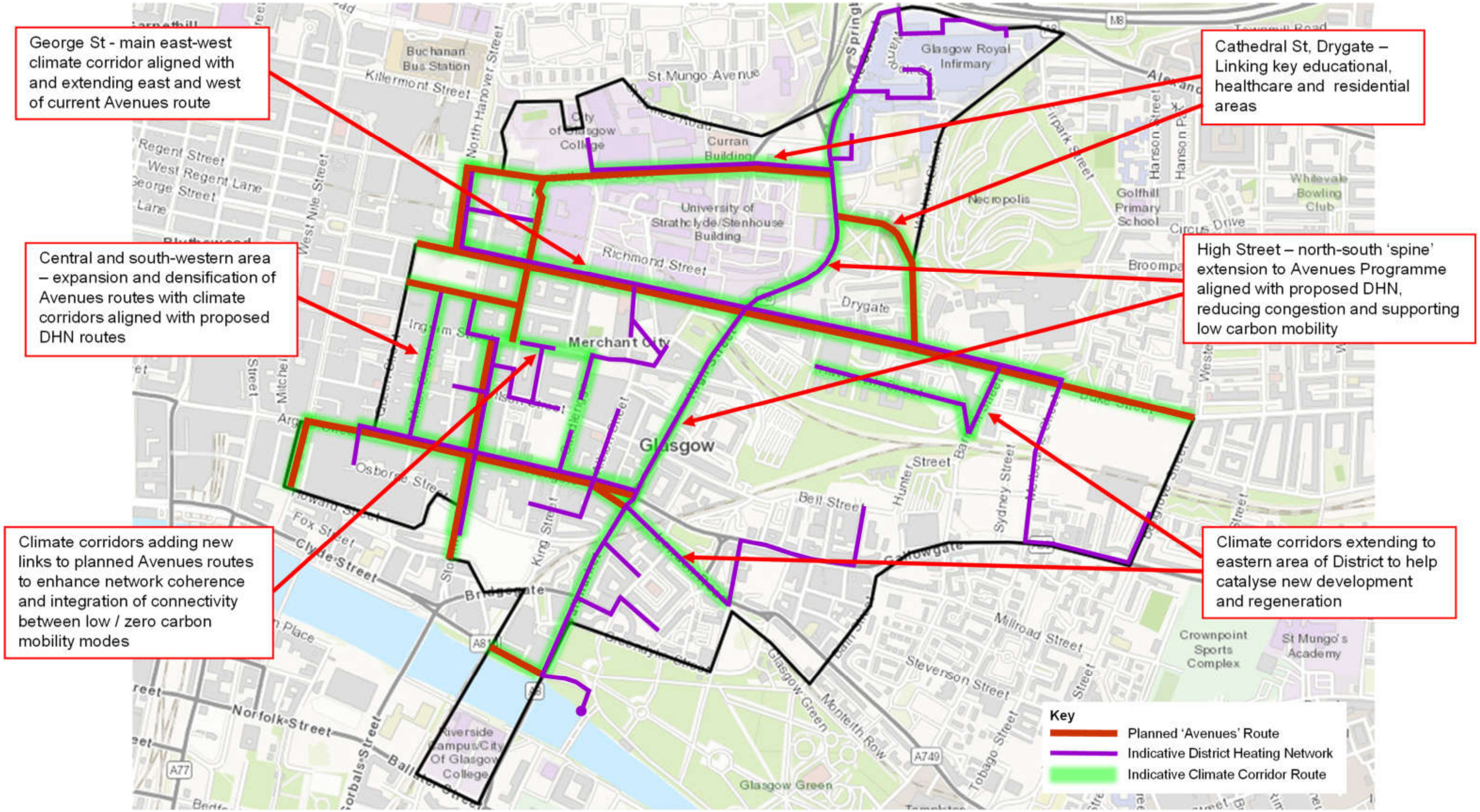


Figure 5-6 – Indicative climate corridors network

Further work is required to develop this initial analysis and recommendations with further details of specific interventions for each climate corridor component. An indication of the further work which will be required is provided in the 2014 study led by Greenspace Scotland, which included contributions from Glasgow City Council and the Glasgow and Clyde Valley Green Network Partnership[17].The figures below present some of the results from this study, which focuses on intervention recommendations for George Street. The analysis first explores existing conditions, including flooding and related topography. It then examines mobility aspects, including road vehicle dominance, as well as overall streetscape features. Recommendations are made for changes to circulation and mobility features highlighting NMU connectivity and new links, and introduction of new streetscape features and green infrastructure, including ground level vegetation, as well as green walls and green roofs.

Figure 5-7 - George St. study area: surface water management

Source: Greenspace Scotland, May 2014.[18]

The study provides quantitative estimates of green cover for recommended interventions, including length and area of green infrastructure provision and number of trees. A particular focus of the study is a comparison between 'modular' and 'non-modular' provision of green infrastructure. Modular provision facilitates installation above or alongside services and can be lifted out of the way to allow access to services, as well as allowing easy integration with other public realm provision such as seating, shelters and bike racks. More traditional non-modular provision is more permanent, customised to specific locations, allows large root systems and facilitates water movement, but is limited to areas where there is no interference with existing services.

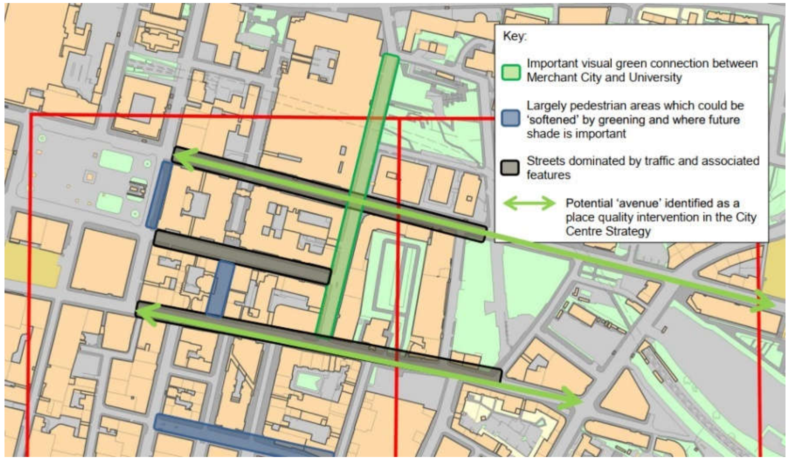


Figure 5-8 - George St. study area: locations for quality of place improvements[12]

The study estimates indicate that, overall, non-modular systems are better able to incorporate higher amounts of green infrastructure in a given street setting. Perhaps not unexpectedly, the study indicates that overall costs for non-modular provision may be expected to be higher due to the higher level of provision, in particular larger fixed trees. The study recommends a blended approach, combining 'quick win' temporary and modular measures with longer term more traditional measures, which would include green roofs and green walls.

The Greenspace Scotland study indicates that achieving a 20% increase in green cover in the study area within Glasgow City Centre is technically possible,

[17] Central Glasgow: retrofitting green infrastructure– a case study, Greenspace Scotland, May 2014. https://www.greenspacescotland.org.uk/climate-resilience-case-studies.

[18] Source: Greenspace Scotland, May 2014.

with a range of options and associated costs. It is also indicated that the recommended approach is fully replicable in other areas of the city.

Since issue of the Greenspace Scotland study implementation of the initial phase of the Avenues initiative has been completed. Figure 5-10, Google Street view of Sauchiehall Street redevelopment shows the level of green infrastructure originally envisaged has been limited in terms of types of cover. Moving forward with development of potential climate corridors in the CNGCID provides a strong opportunity to review the Avenues programme and proactively explore how it can be enhanced and expanded to realise the wide range of socio-economic as well as environmental benefits associated with this form of multi-functional urban environmental improvement.

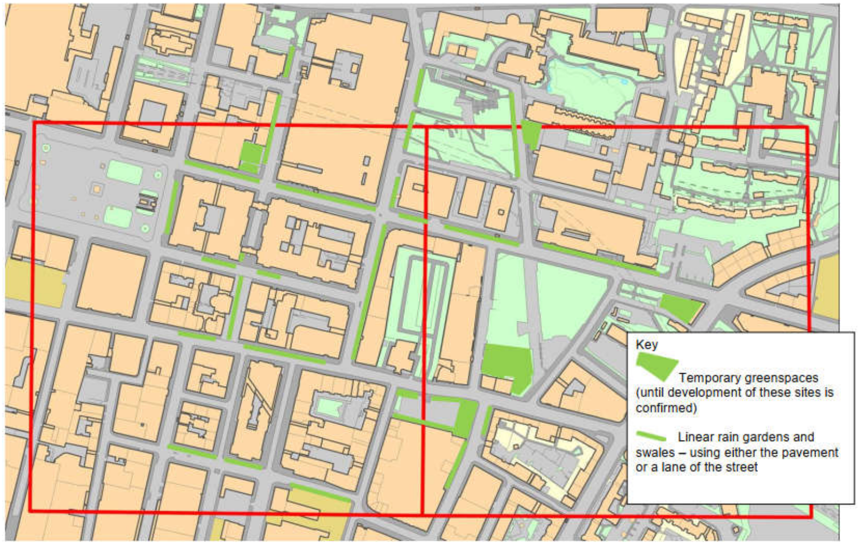


Figure 5-9 - George Street study area: Suggested 'in-street' green infrastructure and temporary space locations[12]

Figure 5-10 - Sauchiehall St looking east, Aug. 2019

5.1.4. Carbon Sequestration

Carbon removals from existing vegetation cover

An estimation of carbon removals from existing vegetation cover within the District was conducted. The extent and characteristics of existing vegetation cover have been estimated based on analysis of land use mapping and associated desktop investigation and characterisation of basic vegetation categories using latest Google Maps satellite imagery. The results of this analysis are summarised in Table 5-1. Further details are provided in the Urban Environmental Improvement Memo [7] of July 2021

Table 5-1 - Initial Analysis of Vegetation Cover within the District[19]

Land Use Category	Area (ha)	Vegetation Cover (%)			
		Trees	Shrubs	Grass	Crops
Green / Recreation Space	14.33	15%	15%	70%	0%
Allotments	0.10				100%
Vacant or Derelict Land	16.33	10%	5%	85%	0%
Total	**30.77**				

Based on the initial vegetation cover analysis and carbon removals factors used, the results of the initial estimation of total annual carbon removals for estimated existing vegetation cover within the CNGCID indicated approximate total annual CO_2e removals of just over **94 tonnes**, or around **3t CO_2e per hectare**, from existing land uses across the three land use categories comprising predominantly vegetation cover.

Carbon Removals from Climate Corridors and Additional Vegetation Cover

Additional annual carbon removals directly associated with extensive implementation of potential climate corridors across the CNGCID are estimated at approximately **10 - 20 tonnes CO_2e**[20], representing up to around a 21% increase on the baseline case. Additional carbon removals from a green infrastructure led approach to new planned development and tree densification in existing green / recreation space within the CNGCID are estimated at around **80 - 90 tonnes CO_2e** annually, representing up to around a 95% increase on the current situation[21]. In total, potential additional carbon removals are estimated at around **90 - 110 tonnes CO_2e annua**lly, which is approximately a 117% increase on the baseline case [1].

[19] Source: Atkins Analysis

[20] Based on green infrastructure estimates from the Greenspace Scotland study, 2014 and an estimated approximate total length of climate corridors across the CNGCID of 10km.

[21] Based on assumed average tree coverage over green / recreation space areas of 50%, with 10% shrub and 40% grass cover; and averages of 40%, 10% and 50% tree, shrub and grass cover respectively across planned new development areas and currently vacant / derelict land.

5.2. Key Findings and Recommendations

There is strong potential for developing a highly effective urban environmental improvement programme for the CNGCID, based on a *climate corridors* concept centred on the multi-function, multi-benefit features of green infrastructure. This will require careful planning and design to ensure that a fully *context and climate sensitive, all-season approach* can fully realise such benefits. Guided by the underlying natural features (topography, soils, drainage, microclimate) and closely sensitive to the different contextual aspects of the predominant urban morphology of the District's various sub-areas, the programme should also be informed by analysis of proven best practice to enable optimal contribution to the aims and objectives of the CNGCID.

While current initiatives, in particular the Avenues programme, provide a solid platform for such an approach within the CNGCID, there is considerable scope for enhancing the planned interventions with a more fully *integrated sustainable outcomes led approach across all key sectors*. The importance of an all-season approach to outdoor comfort in enhancing non-motorised connectivity interventions, for instance, is likely to require close attention. In particular, close coordination of planning and design of energy, movement / connectivity, drainage and green infrastructure and broader public realm, taking full account of projected climate change risks, will be a critical success factor in ensuring the climate resilience as well as carbon neutral objectives for the CNGCID are met.

Overall key recommendations are given below:

- The climate change related risk of increased flooding, both river and surface flooding, urgently needs to be addressed with a strong climate sensitive approach to urban environmental improvements.
- There is a strong opportunity for a climate responsive approach to urban environmental improvement which balances the need for protection from extremes of temperature and precipitation, strong winds and low daylight in the long winter, with optimising benefits from higher temperatures, daylight and solar energy in the relatively short summer.
- The urban environmental improvement programme should be informed by analysis of proven best practice to enable optimal contribution to the aims and objectives of the CNGCID.
- There is scope for enhancing the planned interventions with a more fully integrated sustainable outcomes led approach across all key sectors.
- Although estimated removals from existing vegetation cover represent a small proportion of estimated current emissions, the strong potential to increase vegetation cover, represents an increasingly important means of achieving carbon neutrality within the CNGCID. There are several additional indirect benefits also, including improved city image, tourism, and improved health and wellbeing.
- In total, potential additional carbon removals from extensive implementation of climate corridors and a green infrastructure led approach to new planned development and tree densification in existing green / recreation space are estimated at around **90 - 110 tonnes CO_2e annually,** which is approximately a **117% increase on the current situation**.

6. Transportation Scenario

Transport is a significant contributor to carbon emissions, and emissions within the Glasgow district are interlinked with the wider city and region. Any strategy to reduce emissions cannot be considered in isolation, and the assessment completed through this study therefore considers the city as a whole, including the GCID.

6.1. Targets and Objectives

Within the city, there are a number of targets and objectives which will likely have great influence on transport developments. These include:

- The City's ambition to be Carbon Neutral by 2030
- The target of a reduction in private car traffic of between 30 and 40% in the peaks by 2030
- Improvement in public and active transport to encourage modal shift Improvement in services to improve the vitality of the City Centre
- An ambition to re-allocate City Centre road space for active travel and green infrastructure within the City Centre

6.2. Decarbonisation Approach

As mentioned above, the interventions required must be considered across the city as a whole rather than being focussed on one district in particular. Working with the ongoing plans and developments across the city is likely to be the most successful way forward and will help Glasgow achieve its goal of lowering Net Zero carbon emissions. Within transport, this is primarily achieved by reducing the vehicle distance travelled and reducing the emissions produced when travel is needed. This is done by focussing on the fuel type, vehicle design and driving speed among other factors.

To enable transport decarbonisation, the interventions required can be broadly grouped in to three main categories; Avoid, Shift and Improve. Figure 6-1 summarises these measures.

Avoiding unnecessary travel could be achieved by improved accessibility through localisation and digitalisation of common services, and through improved efficiency by combining or shortening journeys. Shifting measures relates to using more efficient, less energy intensive modes such as high-quality cycling lanes or public transport. Improvement measures refer to those that improve the efficiency and reduce emissions of vehicles used. Electric vehicles and hydrogen vehicles are the key drivers in this category.

Category	*Emissions reduction approach*
Avoid	Reduce overall travel (through reduced trips or length – logistics, land use planning, online activities)
Shift	Increase the proportion of travel by the most efficient modes
Improve	Increase vehicle energy efficiency Move to alternative, less carbon intensive fuel/energy sources

Figure 6-1 - Transport Interventions

6.3. Current and Proposed Measures in Glasgow

There are various activities ongoing in relation to emissions reduction to help achieve the city's target of being Net Zero by 2030. These activities vary from National level (National Transport Strategy and the Climate Change Plan) to local level where the local authority is progressing numerous workstreams to look at transport emissions in the city. Current activity includes transport plans, the Glasgow Connectivity Commission, development frameworks and wider relevant strategies such as the Climate Implementation Plan, Avenues, LEZ, Liveable Neighbourhoods, City Centre Strategy, LTS, Metro project and the Clyde Mission. Engaging with the District Regeneration Frameworks and the City Centre Transformation Plan will be key to influence the city's transport emissions.

Accounting for all of the current activities going on within the city, potential options which have been identified for implementation in the GCID are highlighted in the following sections. More information and background on all the content in this section can be found in the Transport Measures Technical Note. [8]

6.3.1. Active Modes / Personal Mobility

NextBike have several hiring stations for bikes and e-bikes across the city, and they are planning to expand to a further 10 locations. There is an opportunity for GCID to support the NextBike expansion across the city, by providing a cycle hub with facilities (including changing) and / or by providing a charging facility for owned bikes. This could be powered by renewable energy, an example of which is shown in Figure 6-2.

This could help enable further uptake and reduce reliance on cars if the correct infrastructure was readily available for e-bikes and e-scooters. These newer forms of transport help expand the coverage of public transport provision throughout the district.

Figure 6-2 - E-bike charging facility, powered by solar

6.3.2. Public and Shared Transport

By offering more efficient public and shared transport, it will help shift journeys away from the car. Increased data availability on technologies, such as mobile phones, has helped progress this and one such example is through 'Mobility as a Service'. There is an opportunity for GCID to pilot this app in Glasgow and help shape the future of public transport within the district. E-bike and e-scooter hires as mentioned above offer good alternative travel modes, while shared transport options can help provide alternatives where public transport isn't available.

Supporting the development of mobility hubs is also an opportunity for the district, which would help encourage the use of public and shared transport. They would work in alignment with the principle of 20-minute neighbourhoods, which are further explained in the Transport Technical Note. [8]

One of the identified areas for a potential hub is in the North West corner, near Buchanan Street bus station and Queen street, and another option is between Argyle Street rail station and St Enoch metro station.

6.3.3. Demand Management

There are a number of measures already underway within Glasgow, including the Low Emission Zone and rationalisation and relocation of parking provision. Restriction of freight deliveries and the introduction of a Workplace Parking Levy have also been considered. HGVs and diesel powered LGVs would deliver their loads to depot points in the city which would then be distributed / delivered by electric vans or e-cargo bikes. Another option to reduce freight deliveries is joint procurement where businesses in the district will share deliveries. GCID have the opportunity to engage in the development of these plans which will help accelerate the roll out of demand management.

6.3.4. Planning for Localisation and Digital Connectivity

By introducing the 20-minute neighbourhood concept, the number of long trips made within the district is likely to reduce, and the likelihood of walking and cycling between trips is likely to increase. Access to 5G and strong broadband connections are key enablers to ensure remote working, reliable access to services and reducing the need to travel. CNGCID can help accelerate progress in this area by supporting the services and the digital hub component of the mobility hubs mentioned in Section 6.3.2, and helping organisations expand the range of services they offer within the district, both at each of their sites and online.

6.3.5. Uptake of Zero Emissions Vehicles

The uptake of zero emissions vehicles is recognised as a fundamental component to the decarbonisation aspect of transportation. At a national level, the sale of new petrol and diesel cars and vans will be banned from 2030. There is also a Phase 1 proposal from STPR2 which identifies the need to invest in low carbon and alternative fuels, and the importance of a fleet upgrade is recognised throughout Glasgow. Although charging infrastructure is present across the city for EVs, further expansion is not recognised as a high priority due to the limited parking availability within the area. Identified measures which GCID could implement to accelerate progress include:

- Support for further rolls out of EV car clubs and promotion of their use for private and business use
- Targeted support for additional charging points, potentially supported with renewable powered charging stations
- Support for a hydrogen refuelling station

More information on each of these initiatives is detailed in the Transport Technical Note. [8]

6.4. CO_2 Net Emissions of Transport measures

Current CO2 emissions released from transport in the CNGCID stem from car, bus and goods vehicles emissions. Through the "avoid, switch and improve" approach described in section 6.2, it is estimated that car emissions could be reduced by 20-35% in 2030 (relative to baseline for the same year). If CNGCID introduced a Net Zero emissions bus fleet, this would reduce bus emissions by approx. 80% and by implementing consolidation centres and freight restrictions, this would reduce goods vehicles emissions by approx. 10-20%.

There is a national sales ban for all petrol and diesel cars and vans by 2030 which is expected to reduce emissions by approx. 15%.

The cumulative effect on emissions in 2030 is summarised in Table 6-1:

Table 6-1 - Transport Carbon reduction estimate for CNGCID

Scenario	Reduction	Estimated (remaining) emissions kt CO2e/year in 2030	
		low	high
Baseline (assuming no traffic growth from 2019)	baseline	4.78	
National action (sales ban for petrol/diesel cars and vans in 2030)	17%	4.09	
CNGCID measures	~25% to 35%	3.07	2.66

The cost considerations and potential revenue streams arising from these measures have been assessed at a high level given the detail of this study, and it should be noted that they may vary depending upon the approach chosen by CNGCID. The main costs across the measures are staffing, implementation and installation while the key opportunities to generate revenue arise from parking levies, retail & digital services and potentially from the consolidation hubs depending upon the operational arrangements.

As this approach is further developed, the measures, cost implications and opportunities would need to be reviewed in detail.

6.5. Key Findings

- 'Avoid, switch and improve' approach is needed across transport use, to reduce fleet emissions and switch public services to Net Zero.
- Walking and cycling use will have long-term benefits in wellbeing, health and city culture. The 20-min neighbourhood concept can facilitate this.
- Develop a system of freight consolidation through last Mile Delivery Hubs in the and around the district.
- Form a system for e mobility at and including these last mile delivery hubs and at intermodal transport hubs.
- Provide the infrastructure to make these hubs work efficiently - power, road space.
- Provide improved urban realm for walkers and wheelers to move around safely.
- Give pedestrians priority at junctions rather than car. For instance, enable crossings to be 'pedestrian first' and provide seating for people walking to rest and enjoy the green environment.
- The Transport measures need to be implemented consistently across the city. Existing transport plans, and development frameworks need to be highly ambitious and recognise local stakeholder objectives. Behavioural change is needed as much as infrastructure change, and the process of transition needs to be carefully executed.
- Integration with the Avenues programme is a key component to making the decarbonisation measures a success, and particularly the inclusion of High Street as one of the new Avenues. Introducing a dedicated bus corridor and protection of cyclists along this avenue will better connect the communities living around the district. This will help connect both East to West and North to South.
- Decarbonising the transport sector is a key enabler to wider measures in the city, as it gains support from the public.

7. Electric Grid / Smart City

The description of *Buildings* scenarios has highlighted the proposed improvements to the delivery of energy for heating and power, shaping a change in the consumption, and production, of electrical energy in the Innovation District. These updated scenarios are aligned with the previous review of grid infrastructure described in Section 5 of the Baseline Report [1].

In addition to the underlying changes in electrical energy consumption that delivers the carbon neutral scenarios, this study explores the incremental benefit that can be achieved through deployment and coordination of renewable energy (Solar PV) and Battery Energy Storage (BES) to meet various objective *Use Cases.* The reduction in peak demand and minimising carbon intensity associated with electrical grid imports are presented as use cases of flexibility from these Distributed Energy Resources (DER).

7.1. Decarbonisation Scenarios: Electric Grid Impact

For each of the 2030 decarbonisation scenarios, representative time-series profiles of electrical consumption are derived. This forms the basis of subsequent studies exploring the implications for grid capacity (based upon instantaneous peak electrical demand) and the follow-on study of time-series variation in demand and how this can be coordinated with distributed energy resource (DER) flexibility. The 2030 decarbonisation scenarios are:

- Distributed Heat Pumps and Hydrogen Gas (HPH2); and
- District Heat Network, consisting of Anchor and Full deployment scenarios (DHN)

For each of the above scenarios, as well as a 2020 baseline, *LEAR* modelling has approximated the instantaneous peak demand and total annual energy consumption for each building in the Innovation District, highlighting distinction between *Domestic* and *Non-Domestic* Buildings. These metrics have been scaled against a template shape of standardised demand profiles (as used in electricity system balancing) to establish annual profiles of half-hourly electricity consumption to each building. For each study scenario, demand levels are aggregated, based upon postcode, to the demand groups defined in [1] and illustrated in Figure 7-1 - Substation Demand Zones. It is worth noting that the associated substations may have additional demands outwith the Innovation District.

Table 7-1 - Decarbonisation Scenarios - Peak Electrical Demand

Demand Group	LEAR Peak Demand (MW)				
	2020	DHN 2030	DHN % Change	HPH2 2030	HPH2 % Change
Hunter Street	12.6	9.6	-24.4%	10.0	-21.2%
Rottenrow A	24.8	19.4	-21.6%	19.7	-20.2%
Rottenrow B	10.3	9.2	-10.6%	9.3	-9.8%
Virginia Street	11.9	9.2	-22.5%	9.6	-19.1%
Riverside	0.20	0.16	-22.3%	0.16	-22.3%
Totals	**59.8**	**47.6**	-20.5%	**48.8**	-18.4%

There is a net reduction in energy consumption across the Innovation District following implementation of the decarbonisation measures described earlier in the document.

- The net reduction in peak demand between the current baseline scenario (2020) and the HPH2 scenario reflects the implementation of energy efficiency measures, with some net reduction attributed to the transfer of electrical resistive heating to heat pump-based heating.
- Further reductions in electrical peak demand into the DHN scenario reflect the removal of all electrical heating loads from the demand groups (albeit this is offset by the addition of electrical loads introduced by the heat extraction pumps at the River Clyde).

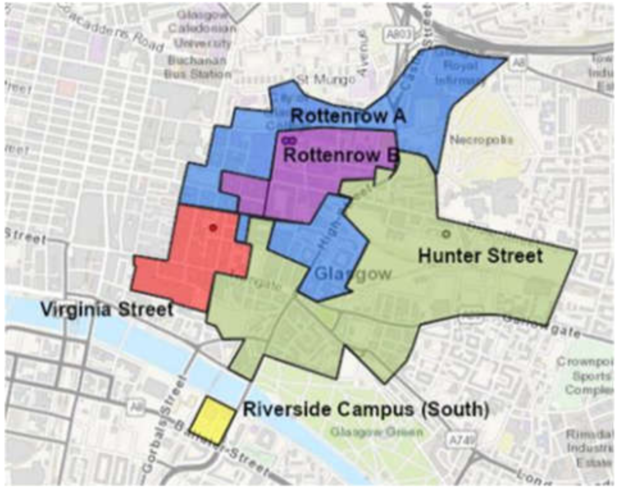


Figure 7-1 - Substation Demand Zones

The decarbonisation scenarios present net-reduction of energy consumption at each demand group, which in turn will drive a net reduction in demand across the substations that supply the innovation district. This suggests that the proposed decarbonisation actions on existing building infrastructure will not trigger reinforcement of network infrastructure across the innovation district. Further infrastructure development however, such as new housing or commercial/leisure units, will result in an increase in system demand.

The DHN scenario will involve the addition of new electrical demand rated at 8.3 MW and 23.3 MW across the *Anchor* and *Full* DHN deployments respectively.

- **New Grid Infrastructure**: Heat Pumps will be located along the River Clyde and will trigger requirement for a new, or multiple new, Primary Substations. New 33 kV infrastructure to supply the heat pumps along the river.
- **Reinforcement of Existing Grid Infrastructure**: The study of headroom in [1] had approximated headroom of 32 MW at Charlotte Street substation, which would supply the DHN heat pumps. This headroom, considered alongside the energy-efficiency-driven reduction in demand elsewhere in the Innovation District, would suggest there is sufficient capacity at the local Grid Supply Point to accommodate the new DHN heat pump load.
- **Further study** by SP Energy Networks would be required to establish the detailed infrastructure requirements to deliver electrical supply to the DHN heat pumps.
- **Coordination** with the *Avenues* project will provide alignment between works to install new grid infrastructure to supply the DHN heat pumps.

The updated study of energy consumption and peak electrical demand has not identified the exceeding of network headroom capacity limits. Hence, across the development scenarios as studied, there is no urgent need for the deployment of Active Network Management (ANM) to mitigate electrical grid constraints[22]. The coordination of DER will however support the delivery of Virtual Power Plant (VPP) use cases, which are explored in the following section.

7.2. Flexibility Use Cases (Virtual Power Plant)

Although no need for Active Network Management has been identified, there are further applications of flexibility, i.e. the coordination of Distributed Energy Resources, with the following Virtual Power Plant (VPP) use cases identified as of value. This flexibility is supported by the deployment of DER to produce and store electrical energy in the Innovation District. The following study of VPP flexibility focuses on the coordination of energy assets from *within* the Innovation District (both production and consumption) to achieve objectives.

[22] Within study scope of energy demand, but wider planned city electrical developments may increase the overall constraints on the network.

Table 7-2 - Flexibility Use Cases

Use Case	Description
Off-Setting Grid Carbon Intensity	Co-ordination of DER to minimise import to the Innovation District from the external electricity grid under periods of high Grid Carbon Intensity Flexibility actions are triggered when Grid Carbon Intensity exceeds a defined kgCO2/kWh threshold.
Peak Lopping	Co-ordination of DER to reduce consumption within the Innovation District during periods of peak demand. Under assumptions that peak demand periods reflect high consumption across the GB network, such actions provide capacity support to the wider electricity system. This also reflects actions that would be taken if further demand growth in the Innovation Zone triggers local grid constraints.

In each of the applications the following deployments of DER and sources of flexibility are considered:

- **Deployment of PV Generation (*DER*):** through LEAR modelling, identified the volumes of PV that can be accommodated across the Innovation District rooftops. PV generation is passive (i.e. non-scheduled) however provides off-setting of local demand and reduces imports from the wider electricity grid.
- **(BES) Battery Energy Storage (*Flexibility*):** considering the deployment of BES to provide schedulable demand off-setting services.
- **Demand Flexibility (*Flexibility*):** Considering the inherent thermal inertial within heating loads, the ability to reduce up to 5% of instantaneous demand for up to three hours in any day.

Whilst the subsequent study of VPP flexibility focuses on the *technical* coordination of DER located within the Innovation District boundary, it is noted that commercial Power Purchase Arrangements (PPA) can align consumption with low-carbon energy production. Such actions however will not directly affect the offsetting of grid carbon intensity, which reflects the practical delivery of electricity via the network infrastructure.

7.3. Deployment of DER, BESS and Demand Flexibility

The following studies explore the value of deploying DER (consisting of PV generation and BES) and the subsequent coordination of flexibility to achieve the Use Case objectives. Both the HPH2 and *Full* DHN development scenarios are studied.

7.3.1. Baseline (Pre-Flexibility) Grid Carbon Intensity

Prior to study of VPP flexibility scenarios, the peak demand Table 7-1 and grid carbon intensity Table 7-2 impacts of the decarbonisation scenarios were viewed in the context of development from the 2020 baseline. The grid carbon volumes in Table 7-3 are derived from the half-hourly electrical demand alongside historical (2019[23]) and forecasted (DHN/HPH2) grid carbon intensity levels.

It is noted that the 2019 average grid carbon intensity for the South Scotland area (35gCO_2/kWh) is significantly lower than the Great Britain average (214gCO_2/kWh), owing to the high levels of renewable and low-carbon energy production in Scotland. National Grid forecasts of Grid Carbon intensity show this will further reduce towards 2030, with a 41% reduction in average grid carbon intensity compared to the 2019 levels.

The HPH2 scenario presents a higher level of Grid Carbon intensity which is associated with greater electrical consumption from the DHN heat pumps. Whilst in isolation this suggest a lower reduction in carbon emissions, the DHN heat pumps will replace alternative sources of energy for heating (Hydrogen and

[23] 2019 is used as reference for Grid Carbon Intensity to eliminate the Covid-19 related low-demand outlier behavior found in 2020 datasets.

Natural Gas) in the HPH2 scenario, each of which will have associated carbon emissions.

Table 7-3 - 2030 Grid Carbon Associated with Electricity Demand

Demand Group	Grid Carbon (tCO_2)				
	2020	DHN 2030	DHN % Change	HPH2 2030	HPH2 % Change
Rottenrow A	3,257	1,464	-55.0%	1,527	-53.1%
Rottenrow B	1,386	695	-49.9%	713	-48.6%
Hunter Street	1,573	667	-57.6%	741	-52.9%
Virginia Street	1,248	564	-54.8%	593	-52.5%
Riverside	23	11	-54.4%	11	-54.4%
DHN Heat Pumps	-	1,824	-		-
Totals	**7,488**	**5,225**	-30.2%	**3,584**	-52.1%

7.3.2. DER Modelling

LEAR modelling identified rooftop footprint to accommodate approximately 24 MW of PV generation across the Innovation District. This has been distributed across the demand groups as presented in Table 7-4. BES deployment is based upon assumptions that BES storage density will continue to improve towards 2030, improving the capacity that can be accommodated across small footprints[24].

Table 7-4 - DER Deployment Levels

Demand Group	PV Capacity (MW)	BES Rating (MW)	BES Capacity (MWh)
Rottenrow A	7	2	8
Rottenrow B	4	2	8
Hunter Street	8.75	2	8
Virginia Street	4	2	4
Riverside	0.25	1	2
DHN Heat Pumps		1	2
Totals	**24**	**10**	**32**

[24] BES deployment capacity approximated as development from existing density levels (approx. 1.4MWh per 20ft container) and assuming distributed across Demand Group

7.3.3. Use Case Study: Peak Lopping

Findings from the study of peak demand coordination is presented in Table 7-5. The study coordinates all DER to achieve the objective of reducing peak demand.

Table 7-5 - Demand Peak Lopping Scenario Results

Demand Group	Peak Demand (MW)					
	DHN Before	DHN After	% Delta	HPH2 Before	HPH2 After	% Delta
Rottenrow A	19.4	17.4	-10.2%	19.7	17.7	-10.2%
Rottenrow B	9.2	8.3	-10.3%	9.3	8.4	-10.3%
Hunter Street	9.6	8.5	-10.5%	10.0	8.9	-10.5%
Virginia Street	9.2	8.3	-10.3%	9.6	8.6	-10.2%
Riverside	0.2	0.1	-10.9%	0.2	0.1	-10.9%

DHN Heat Pumps	23.3	23.3	0.0%	-	-	-
Totals	**70.9**	**66.0**	**-6.9%**	**48.8**	**43.8**	**-10.3%**

In addition to the reduction in peak demand, flexibility measures reduce overall energy consumption by 9.1% in the DHN scenario and 13.3% in the HPH2 scenario.

7.3.4. Use Case Study: Grid Carbon Off-Setting

The study coordinates all DER to achieve the objective of reducing Innovation District demand during periods where grid carbon intensity exceeds 40gCO2/kWh.

Table 7-6 - Grid Carbon Off-Setting Scenario Results

Demand Group	Grid Carbon (tCO2)					
	DHN Before	DHN After	% Delta	HPH2 Before	HPH2 After	% Delta
Rottenrow A	1,464	1,325	-9.5%	1,527	1,387	-9.2%
Rottenrow B	695	607	-12.6%	713	626	-12.3%
Hunter Street	667	498	-25.3%	741	571	-22.8%
Virginia Street	564	485	-14.0%	593	514	-13.4%
Riverside	11	5	-53.4%	11	5	-53.4%
DHN Heat Pumps	1,824	1,811	-0.7%		-	-
Totals	**5,225**	**4,732**	**-9.4%**	**3,584**	**3,102**	**-13.4%**

7.4. CO_2 Net emissions of Grid/Smart City Measures

Scenario 2 (the DHN) has lower rate of decrease in grid carbon emissions compared to the HPH2 scenario, however due to the increased electrical consumption off-setting gas heating loads, the deployment and coordination of DER introduces **a 9.4% reduction in grid carbon emissions** from the updated 2030 levels.

In the HPH2 scenario the coordination of DER flexibility can **produce 13.4% reduction** in Grid Carbon Emissions compared to the passive equivalent, supported by the scheduling of PV production alongside BES scheduling and demand flexibility.

When compared to the 2020 emissions associated with the LEAR modelling electrical demand, the inclusion of DER VPP flexibility in the DHN and HPH2 scenarios produces a **37%** and **59%** reduction in electrical-related carbon emissions.

7.5. Key Findings

<u>Demand Growth and Need for Active Network Management</u>

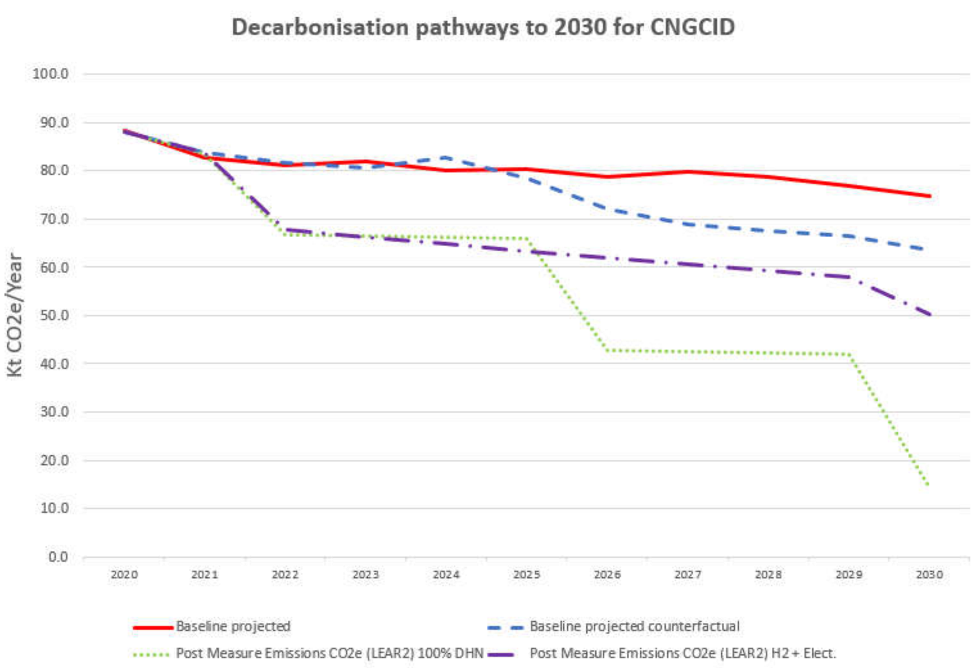
The study of peak electrical demand from the LEAR modelling has identified that all modelled developments fall within existing network headroom capacity limits. There is no urgent need for Active Network Management (ANM) to address electrical grid constraints under the studied conditions.

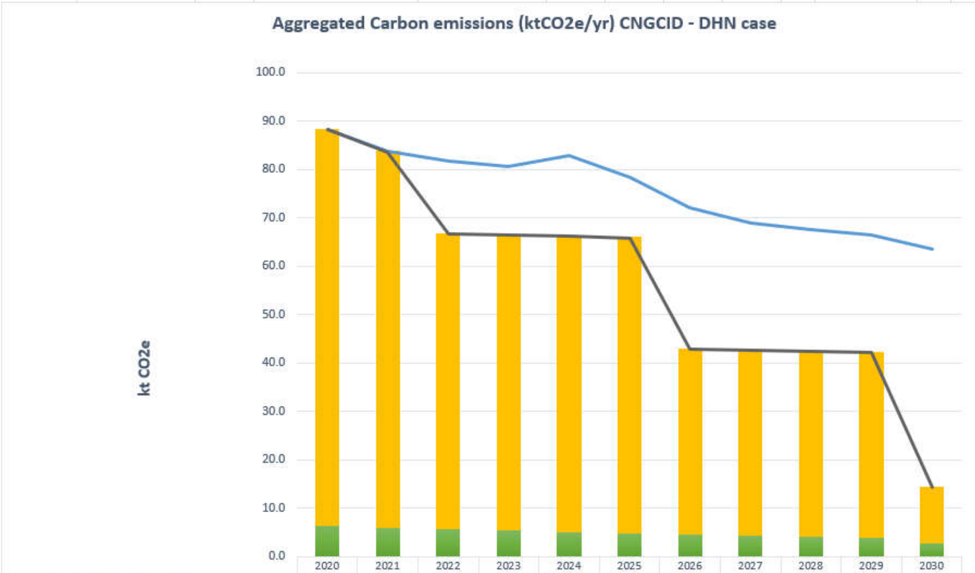
<u>DER Deployment and Flexibility</u>

The deployment of DER (PV and BES) and subsequent coordination of these assets can deliver flexibility objectives to minimise peak load (in cases of future emergence of constraint) and off-setting carbon emissions associated with the grid electrical supply.

The deployment of PV and BES (at the levels studied) will facilitate net reduction in peak demand by approximately 10% across the existing substations in the Innovation District. Due to the nature of the DHN Heat Pump operating profile, the DER coordination cannot sufficiently reduce peak demand across a full day of operation.

8. Aggregated Carbon Emissions





	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LEAR 2 Buildings (100% DHN)	82.1	77.9	61.2	61.2	61.2	61.2	38.3	38.3	38.3	38.3	11.8
LEAR 2 Environment	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20
LEAR 2 Transport	6.2	5.9	5.6	5.3	5.1	4.8	4.6	4.3	4.1	3.9	2.7
Baseline projected counterfactual	88.2	83.8	81.7	80.6	82.8	78.4	72.1	68.9	67.5	66.4	63.5
Post Measure Emissions CO2e (LEAR2) 100% DHN	88.2	83.6	66.6	66.4	66.1	65.8	42.7	42.5	42.3	42.1	14.2

Figure 8-1 - Aggregate decarbonisation pathway (left) and Carbon emissions by sector for DHN (right)

The decarbonisation pathways chart presents the study results of the two selected scenarios against the LEAR 1 modelled baseline, but also against a ‘baseline projected counterfactual’ case which includes modest assumptions of (5% year on year) reduction in heat demand (due to improvements in building fabrics mandated by building standards) and a (10% year on year) reduction in appliance demand. **Scenario 1 achieves a 42% reduction** from the baseline, and **Scenario 2 achieves a 84% reduction**, taking the residual emissions to 14.2 ktCO_2/yr for the LEAR 2 modelled 2030 case. It is likely a level of offsetting would be required to achieve climate neutral status by 2030, however some of the measures discussed in the Leading the Way case (Section 9) could bring this even closer to Net Zero emissions.

8.1. GIS Mapping Output

The updated GIS portal allows access to the study outputs spatially within boundary. [accessible here with approved login; http://strath.atkinsgeospatial.com]

Maps are available with several layers that can be “turned on/off”. These include: LEAR 1 energy demand data, LEAR 2 energy demand data, buildings in district, CO_2 emissions, utilities, waterways, land use (incl. planning applications), socio-economic impact and travel.

9. Prioritisation of Measures

For the packages of measures considered in this study, a red-amber-green (RAG) scoring assessment was applied to determine the priority order of adoption, but also to indicate potential challenges to implementation. The RAG scoring was applied to each of the assessment criterion (detailed in Appendix C), which were as follows:

1. Carbon saving impact (CO2e) to 2030 (CNGCID target)
2. Embodied energy (CO2e impact) - materials/construction
3. EPC technical complexity / integration ease
4. deliverability-technical
5. deliverability-political, other
6. Risk -safety, environmental, security, reputational
7. CAPEX- scale of funding needed
8. O&M - annual running costs (excl. fuel)
9. Fundability
10. Additional benefits
11. Alignment with existing Supporting Policy/regulation
12. Future proof - climate resilience

The results from this workshop exercise, are given below with an extract provided in Appendix C, and in issued deliverable 5200737-PM-WBK-002 [9]. It should be noted that the ranking applied to each of the measures has been formed on the basis of a series of assumptions, meaning the ranking could change if the weighting applied to the criterion was changed. This may be the case depending upon the investment angle, however the ranking currently shown below allows a basis of comparison which suggests an order of prioritisation/implementation. Note that the carbon saving impact is not a weighted factor, so larger decarbonisation 'packages' like the DHN, Scenario 2 are not prioritised on this measure alone.

Table 9-1 - Ranking the 'packages of measures'

Measure Proposed	Rank #	Comment
Environmental measures; green space, allotments, derelict land use ***("Transformational case")***	1	Although modest (relative) carbon saving rewards in the short term (before 2030) and alignment with city plans, the cost and impact to achieve a reduction in carbon emissions is minimal and implementation in the short term does reap long-term carbon gains. Also, increased green spaces offer an abundance of indirect benefits, with improved tourism, wellbeing and climate resilience as well as being aligned with city plans.
ESC measures modelled; Building energy material efficiency improvements package, includes *internal insulation, double glazed, loft*	2	These measures are easy relative wins versus the carbon saving returns. The measures also act as critical enablers to all major climate neutral pathways and are directly aligned with city planning and policy. Achieving a high level of

insulation to max, smart heating controls, fixed lighting demand reduction (-24%), appliance demand reduction (19.5%)		building thermal performance is essential to reaching Net Zero status and offers wellbeing improvements.
Environmental measures; 'Transformational case' but with increased action, inclusion vertical gardens ***("Leading the way case")***	2	More ambitious environmental measures will be difficult to achieve with quantity of historical buildings and variety of ownership types.
Transport measures (achieve 25% reduction from transport baseline); *active modes, public transport upgrades, demand management, digital hub, EV and charging, shared transport,* ***("Transformational case")***	4	scoring reveals these are easy wins, although carbon saving is modest (before 2030), the 'additional benefits' are significant around wellbeing and improved lifestyles, which are long-term evolving concepts to change human behaviours but have the potential for significant long-term decarbonisation.
Transport measures; similar measures but increased roll out, and uptake achieving 35% reduction from baseline ***("Leading the way case")***	5	Achieving a UK leading strategy will be ambitious and may not be met by 2030. It would require aligned ambition and coordination across a multitude of stakeholders.
Virtual Power Plant, VPP (PV and BESS coordination) ***("Transformational case")***	5	Can offer lower grid intensity, and flexibility electrical use, therefore also benefiting from low market pricing. Avoids network reinforcements so helps meet 2030 timescales.
DHN 'anchor loads' network adoption, **("Scenario 2, Transformational")**	7	Significant 'guaranteed heat offtakers' are needed for the Phase 1, 'Anchor loads' DHN. This may mean breaking existing commercial contracts.
Hydrogen (up to 20% blend in grid) + local electrification **("Scenario 1, Transformational")**	8	Some decarbonisation benefit and a credible pathway beyond. However, the delivery is eternally influenced, and there is a risk to CNGCID showing no visible progress in project timeframe (by 2030).
DHN; full network adoption ("Scenario 2, Leading the Way")	**8**	**This option is not without technical and commercial challenge, but offers a credible, deliverable pathway to Net Zero (albeit it is likely to be delivered after 2030).**
Hydrogen (>20% blend in grid) + local electrification **("Scenario 1, Leading the Way")**	10	Within project timeframe delivery is unlikely and dependant on a number of external factors.

Table 9-1 provides an indication on the likely pathway and narrative to reaching climate neutral status. The environmental measures should start now and target a 'Leading the way' approach. The building measures need prioritised for action in the short term, as they are critical to delivery of later decarbonisation scenarios (e.g. DHN). The transport measures next offer modest relative carbon savings, but an opportunity to showcase demonstration projects, and also change public behaviours around climate change. This could act as the catalyst to more significant infrastructure changes needed like the Scenario 1 and 2 presented. Of the two main scenarios considered it also shows that the DHN comes out on merit against the criterion. This is largely because it offers a credible pathway to climate neutral (or very close to) within the project timescales. The residual carbon impact of this scenario is then largely due to carbon intensity in the grid, which can be reduced further still through concepts like the VPP, and with BESS coordination. **[The 100% DHN only, or Scenario 2 is the selected case for focus in Sections 8, 9, 10]**

10. Leading the Way Scenario

The aggregated carbon emissions discussed in Section 6, show an 84% carbon reduction is possible, but 'Scenario 2' then becomes reliant on grid carbon intensity dropping to Net 0g CO2/kWh, which will not happen in the short/medium timescale. Therefore additional 'Leading the Way' ambitious decarbonisation methods should be explored to minimise the residual emissions. The most credible measures identified through this study are as follows:

- Utilising VPP technology to reduce carbon intensity of the grid by up to 9% (see Section 5), e.g. Maximising the benefit of BESS & Solar PV
- Enhanced building control of heating through Minibems technology (discussed in section 3.5.3) can offer maximal COP performance, and therefore greatest value per unit electricity from the Grid
- Enhanced thermal storage can offset the need to use carbon intensive electricity
- A consortium of Stakeholders could invest in Direct CPPA (Corporate Power Purchase Agreements) to offset demand through investment directly in procured clean generation
- Additionality measures should be maximised (e.g. DAC and Solar PV)
- Additional heat sources (as discussed in Section 3.5.4) should be investigated as a priority to see if they can reduce the central WSHP thermal demand. From initial reviews, this could offer ~10MWth.
- DAC technology as a mean to capture CO2 residuals. Technology could be installed early though to additionally offset CO2 emissions.

10.1. Scottish Context & Support

The challenge to achieve 100% uptake for a DHN (as proposed in Scenario 2) is substantial and may not be practical. However, Scottish government are very supportive of DHN and so the political and policy support in Glasgow is very strong. Based on the Heat Networks Scotland Act, Scot gov want to see the following actions by 2030:

- Reduce emissions from heat by 68%
- All homes to reach EPC of C (supported through Energy Efficient Scotland)
- 50% (1 million) homes replaced gas heating with low carbon alternative
- 200,000 homes switching to 0 carbon alternative heating

Further discussion on the Policy context and support is given in 5200737-PM-TCN-003-A-01 Climate Neutral GCID Policy Review. [10]

Supporting initiatives for a DHN that Scotland is championing include the HEAT NETWORKS (SCOTLAND) ACT, passed February 2021. This will be achieved through:

- Local Heat and Energy Efficiency Strategies (LHEES); introduced in 2016 LHEES was introduced to pilot and test methods for creating an LHEES. It also sets out a guidance framework to develop
- The Transition Programme Decarbonisation Fund,
- The Energy Efficiency Transition Programme,
- The District Heating Loan Fund

Further to, and in support of these initiatives, are the Scotland Heat Map tool, the Heat Network Partnership, and progressing the Regulation of Heat Networks.

There is also a new commitment of at least £1.8 billion over this parliamentary session, allowing us to accelerate energy efficiency upgrades and renewable heating deployment, and creating new jobs and supply chain opportunities across Scotland.

In addition, in Glasgow two key DHN have provided demonstration of the possible:

- Queens Quay WSHP DHN; detail available here
- Heat vision work in Glasgow, available here

11. Funding and Bankability

Ikigai undertook a high-level review of investor considerations and potential structures for the proposed district heat network to serve the CNGCID. The review has been performed on the basis of the information shared with Ikigai by Atkins, Glasgow City Council and Strathclyde University in a workshop held on 21 June 2021 [3]. Please refer to Reference [2] for the full report.

The bankability analysis has been undertaken on the assumption that:

a) the Project will be supplied with heat derived entirely from water-source heat pumps utilising the Clyde River and will consider the technically proven options for transitioning the use of the existing CHP plant operating at Strathclyde University (amongst other CHP sites in Glasgow) to fully decarbonised energy centres, whether by way of fuel-switching to hydrogen or carbon capture, reutilisation and/or storage; and

b) maximising the attractiveness of the Project to private sector investors is a key objective, while balancing this with delivering 'best value' to public sector offtakers, affordable heat to residential and commercial users and achieving carbon neutrality.

When completing the analysis, Ikigai provided an overview of current and industry leading perspectives of prospective investors into DHNs in the UK compared with other markets, noting the specific advantages of DHN investment in Scotland over the rest of the UK.

Ikigai have considered key project decisions that will need to be resolved at the next stage of the project lifecycle, which are focused on the existing DHN, the anchor customers, in particular the hospital, and the capacity to connect 'The Project' to other networks planned or existing across Glasgow to create scale, to enable raising of private (and public) sector funding. Partnering opportunities to maximise social and economic impact were assessed, setting out the pros and cons of different types of partners; and the possible public-private funding structures suitable for different stages of the Project lifecycle were noted for further discussion.

The review determined that it is too early to determine the exact funding / shareholding structure that will be appropriate for this Project. Structuring will be affected by the factors to be further refined at the next stage of pre-commercialisation analysis (Phase 2) such as technology choice, counterparty risks and commercial arrangements, the types of risk Glasgow City Council wishes to retain and those it wishes to allocate to the private sector and Project scale.

However, assuming an objective to maximise the proportion of private sector investment made available post Phase 2, it will be important to outline certain fundamental financing principles when engaging with private sector investors. Based on investor engagement, Ikigai would recommend that these include the following, subject to further discussions with the Steering Committee and legal, regulatory, financial, tax and accounting advice:

a) Consider early incorporation of a limited liability company for the sole purpose of developing the Project (the "**Project SPV**"). Such Project SPV will be profit making but could be limited by guarantee or by shares – legal advice will be required to determine the optimal corporate and governance structure. All Project-related rights and undertakings should be held by this Project SPV (or its subsidiaries – see item (e) below).

b) Make any public grant or debt funding made available conditional on satisfying requirements with respect to (i) affordable and reliable heat to be made available to residential heat consumers; (ii) Net Zero targets; and (iii) local content, ensuring that the covenants imposed are realistic and achievable.

c) Maximise leverage made available to the Project SPV, but only to the extent there is a pricing advantage vis a vis equity, though initial feedback suggests that construction debt may not be significantly cheaper than retail/institutional equity for DHN.

d) Consider refinancing of higher cost construction capital 12-18 months post-commissioning to facilitate investment by funders whose investment mandate is limited to operational assets and engage now with those funders in order to optimise overall cost of capital.

e) Adopt a "generator build" model which consolidates ownership of the energy centre, primary and secondary heat and electrical networks and customer connection equipment in the Project SPV, but also provides (e.g. by way of separate subsidiaries of the Project SPV) for refinancing (whether by way of debt and/or equity) of "esco" and/or "pipeco". This is important as different investors are attracted to different types of asset – long-term low-cost capital may have a preference for investment into only pipeco which offers a stable, inflation linked, availability-based payment from customers over 25+ years, whereas private equity may be more interested in the risk profile (and higher returns) associated with an energy centre investment.

f) Offer a comprehensive security package to all debt providers, in particular over assets which may have residual value in circumstances where the Project does not become operational (i.e. real estate), in order to optimise that cost of capital and ensuring that private sector debt providers rank at least *pari-passu* with public sector debt providers. In the case of the Scottish National Investment Bank, we would recommend discussing their appetite for providing junior debt / quasi-equity financial products (as they have previously confirmed they are able to do).

The Technical Memo [2] should be read as a starting point for further discussions at the next stage of pre-commercialisation and it has been assumed this will include, as a minimum, in the following order of priority:

a) preparation of a stakeholder engagement plan including identification of potential anchor offtakers, quantification of the scale, profile and timing of firm current and future demand, understanding of the technical, legal and commercial pre-conditions / interventions required for delivery – see, in particular, Part 2 of this report for key questions for discussion with stakeholders;

b) preparation of a technical concept design and draft programme for additional energy centres and the network expansion (including necessary metering, demand management and other behind-the-meter works) taking into account the potential for alignment of programme and procurement with other aspects of the GCNID, such as climate adaptation measures, broadband and EV charging network rollout – see Atkins main report;

c) preparation of a high level financial model (the minimum characteristics of which are set out in Part 1 of this report) which will necessarily be refined over time;

d) consideration of optimal corporate structuring and governance arrangements for the Project delivery vehicle and private finance structuring and sourcing options – see Part 4 of this report;

e) preparation of a planning and environmental impact appraisal, including a detailed whole heat (and power) network decarbonisation plan; and

f) confirmation of available public grant funding to support the next stage development activities. Such activities will include preparation of a FEED study, a planning application for the additional energy centre(s), survey works, construction procurement and contract negotiations with anchor offtakers and relevant landlords (i.e. "Phase 3").

Following completion of the above points, Ikigai recommend that a detailed private sector investor (both debt and equity) market engagement exercise be undertaken to obtain precise feedback on risks identified, mitigants and proposed allocation, potential funding / shareholding and governance structures and expected returns.

12. Preliminary Financials; Cash Flow Model Analysis

Initial (high-level) financial modelling has been completed to understand the investment profile for the district heat network based on 'fixed assumptions' from industry case studies. This has been based on detailed review of the major contributing CAPEX and OPEX components. For instance, including the utility cost, annual operational & maintenance costs, DHN component & construction costs and applicable revenue income streams. The expenditure and income have been profiled on an annual basis up to a 40year period.

Figure 11-1 illustrates the cashflow over 25 years, while Figure 11-2 shows the cashflow over 40 years. Table 11-1 below highlights some of the key input metrics from the cash flow model. These input metrics are considered fixed assumptions to frame the minimum investment case, as discussed in section 10.

Table 12-1 - Key Financial Input Metrics

Metric	Value
NPV discount rate	8% (this is considered the minimum investment basis, see Section 10)
Term of Investment	25 and 40 year reviewed
Electricity price	Target PPA pricing of 5p/kWh for the first 20 years
Carbon Price	£40 / tonne of CO_2 has been assumed for the UK ETS scheme as a source of income. Considered conservative and has been used to demonstrate the high volatility of the market.
CAPEX for Phase 1	£55,785,318 (value provided from COMSOF)
CAPEX for Phase 2	£112,823,812 (value provided from COMSOF)

The following assumptions were applied to the financial model:

- The cash flow model is based on 100% uptake of DHN. Phase 1 DHN was assumed to be commissioned by 2025 and Phase 2 (100% uptake) by 2030.
- A rate of inflation of 2% has been applied, taken as an average over the last 4 years. Inflation has been applied to the CAPEX, OPEX costs, heat sales, elect. cost.
- Business rates have a relief rate of 90% in alignment with current Scottish Government Policy for new district heat networks supplied by renewables.
- Preliminary, engineering, project management and contingency costs have been included.
- Income revenue through heat sales and grid flexibility (by providing grid services) have been included.
- The capital expenditure (CAPEX) cost for the equipment included within the model has been taken from the values provided by COMSOF.
- ESC provided LEAR 2 model has provided the annual energy demand inputs to the model.
- The operation & maintenance (OPEX) costs are derived from the BEIS Green Book [11] using the utility prices to generate gas and electricity costs, while the costs for insurance, business rates, staff/management costs, energy centre, network & equipment operation and maintenance have been calculated using industry standard benchmarks.
- Energy efficiency measures have been included as a package of works totalling ~£7M. It is assumed all eligible buildings will undergo building modifications if relevant. These works have assumed to be completed by 2022, as pre-requisite conditions to the DHN.
- A £250k/yr cost has been included for the maintenance and operational costs of the energy centre and the DHN. This annual cost is potentially high annually but will ensure that an extended life of 30yrs is achieved for the major components of the DHN.

- Design life of major components is 30 years, yet the DHN distribution has a design life of 50yrs+. This design requirement would however need to be contractually obliged during the procurement process, as it will determine material selection.

Based on the assumptions used, and benchmarked against recent industry examples the indicative investment profile is given as follows:

Table 12-2 - Key Financial Output Metrics

Investment case	Result
20 year	IRR 5.6%, NPV -£24M
25 year	IRR 7.9%, NPV -£1.2M
40 year	IRR 9.9%, NPV £+35M
Indicative heat pricing	15p/kWh[25]

The resultant cashflows for both a 25-year investment and 40-year investment are shown in Figures 11-1 and 11-2.

12.1. Key Findings

It was found that the strongest influencers on the investment case are:

- Inflation, which was assumed at 2%
- Tolerable heat pricing, which to achieve a minimum IRR of 8% was found to be ~15p/kwh (considered too expensive in the current market)
- Design life before major overhaul. It was essential to maximise life of the asset through higher than typical annual OPEX costs, this means a 30yr design life is achievable and so pushes back the timescales for replacement of major components.
- Agreeing a very competitive electrical price per unit (kwh), which is likely achieved through private wire agreement or investing in commercial Power Purchase Arrangements (PPA) to secure fixed low carbon production. A price of 5p / kWh is desirable, which is 50% of current market standard (BEIS figures), yet there are Scottish based precedents for this.

[25] The price of unit heat is relatively high and if fixed at a closer to a target market value (e.g. 10p/kWh) it would push out the investment term or lower IRR within the targeted 25 & 40yr periods.

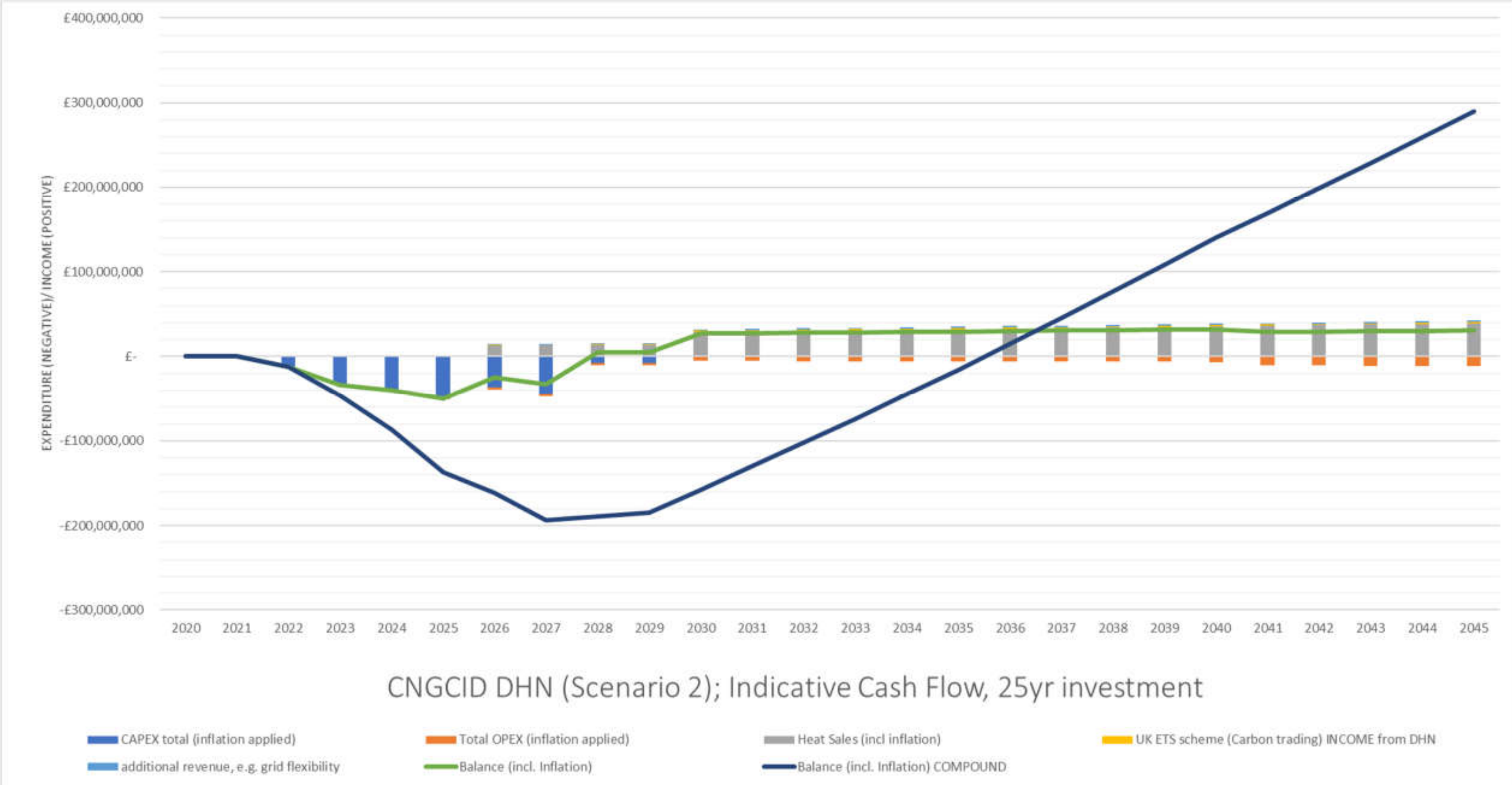


Figure 12-1 - Indicative Cashflow with a 25-year Investment

As can be seen in Figure 11-1 the investment is cash negative from 2022 to 2027, due to the initial capital investment for the heat network. This is shown by each of the blue bars on the chart between 2022 and 2029, which are representative of the split of CAPEX spend, phased per year. After 2027, the net balance starts to move positive as the total revenue from the heat sales, grid flexibility and UK ETS scheme start to impact the cashflow model. The revenue then begins to accumulate over the next 15 years to result in a (close to) neutral NPV balance and IRR of 8%. Beyond this timeframe, the investment case strengthens as is shown in Figure 11-2 below:

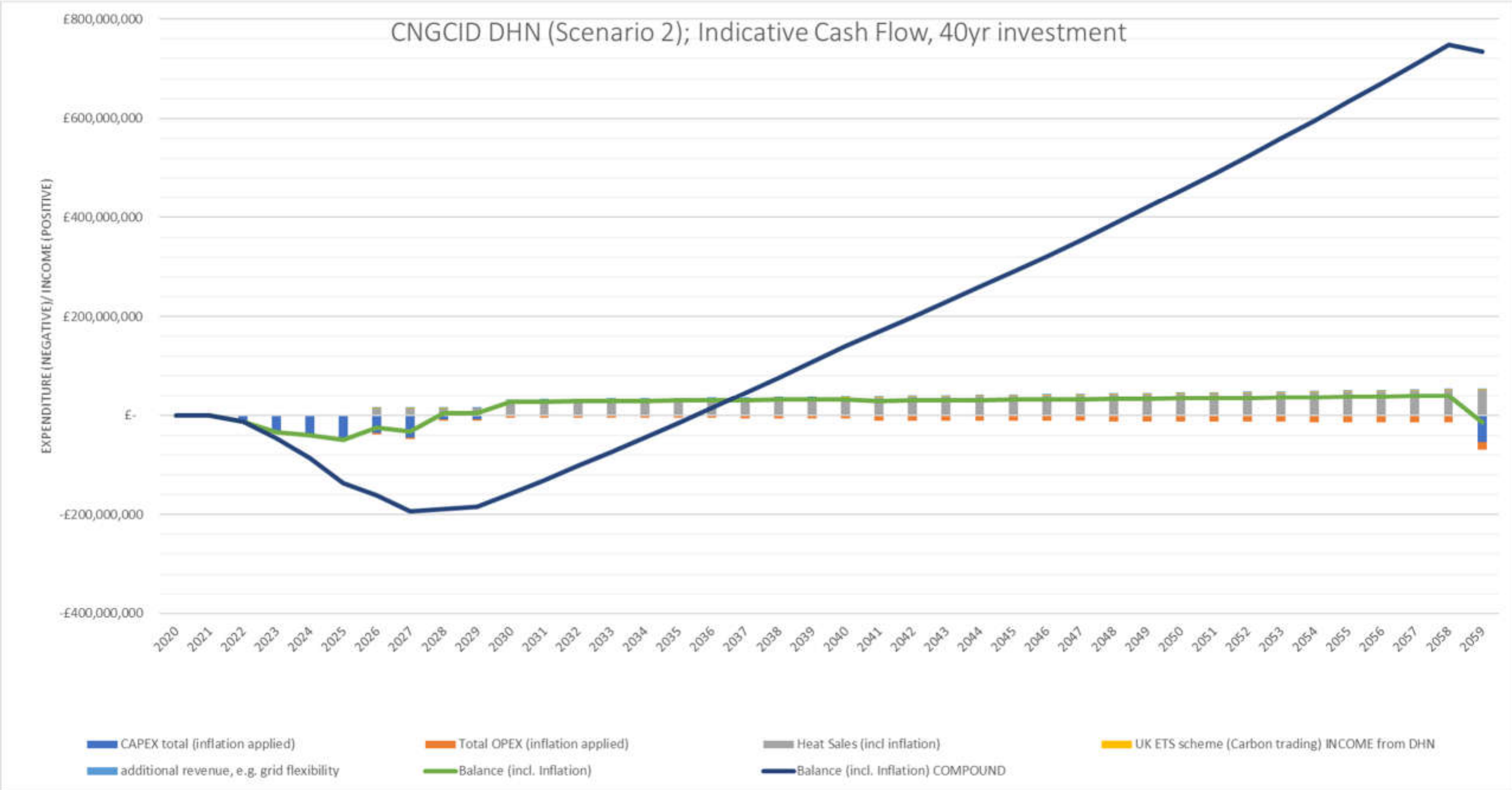


Figure 12-2 - Indicative Cashflow over 40 years

For the 40-year investment case the income revenue (from heat sales, UK ETS scheme and grid flexibility) compound after 2037, resulting in the cumulative balance growing annually. The design life of major components is set at 30yrs, which is starting to be shown in 2059, where major component replacement creeps in. While this long design life is aspirational, existing DHN have shown it is very achievable if a high annual opex is set to keep the equipment running at high efficiency. This in turn offers higher marginal performance.

Accounting for this additional investment, the IRR for a 40-year investment is 9.9% with NPV of £35M, thus resulting in a positive return on investment.

13. Key Findings and Actions

13.1. Key Findings

The District Heat Network '100% uptake' Scenario provides a credible pathway to 84% emissions reduction from baseline, and innovative grid flexibility approaches can offer a further 9% reduction. These measures coupled with some residual GHG emissions capture technology (and nature-based solutions) provide a pathway to Net Zero by 2030.

- The emissions associated with buildings, 82.1ktCO2e/yr, are generated in majority from building heat demands, through use of grid services (gas and electrical) contributing 93% to the baseline CNGCID carbon case for 2020. A step change approach is needed to reduce the heating demands of buildings within district. Reducing demand through improved building energy efficiency measures and a city-wide District Heating Network (implemented in 2 or more phases) has been identified as the most feasible approach to maximise the contribution of carbon savings in the Climate Neutral Glasgow City Innovation District (GNCID). Identified anchor loads consume 50% of the CNGCID annual heat demand between 75 buildings. These include the Royal Infirmary Hospital, University of Strathclyde, City of Glasgow College estate campuses and St Enoch Shopping centre providing a robust base case to initiate a bankable initial phase of DHN development.
- Transportation is the second major contributor to the current carbon case for 2020, emitting 6.2 ktCO_2e/yr. **The approach to decarbonising transport must be implemented consistently across the city**. Through central coordination, existing transport plans and development frameworks need to be highly ambitious and recognise local stakeholder objectives. Behavioural change is needed as much as infrastructure change, and the process of transition needs to be carefully executed.
- Decarbonising the transport sector is a key enabler to wider measures in the city, as it gains support from the public. An 'avoid, switch and improve' approach is needed across transport use, to reduce fleet emissions and switch public services to Net Zero.
- Walking and cycling use will have further long-term benefits in wellbeing, health and city culture.
- Delivery Approach - There is strong and u**nique opportunity to integrate a whole systems approach**, including energy, movement / connectivity, drainage and green infrastructure and the broader public realm. Through coordinated planning of these aspects, the realisation of benefits from so-called 'climate corridors' sits at the core of a successful approach to achieving climate neutrality within the district. This whole systems approach sets Glasgow apart from other cities.

  It is vital that modified layouts and enhanced scope of **the existing Avenues Programme are adopted. This is an exciting opportunity to provide a globally leading example** for densely populated regions, all of which are similarly challenged with climate crisis mitigation requirements as the CNGCID.
- There is opportunity to utilise the existing complimentary Local Heat and Energy Efficiency Strategy (LHEES) in the deliver delivery of this vision. The LHEES needs to be integrated into the whole system solution complimenting the low carbon transport, environmental, climate resilience and well-being initiatives.
- There is a strong potential to increase vegetation cover and urban canopy, walls and roofs, representing an increasingly important contribution in achieving climate neutrality within the CNGCID. There are several additional indirect benefits also, including improved city image, tourism, and improved health and wellbeing. This aspect applies to existing and new built environment.
- In total, potential additional carbon removals from extensive implementation of climate corridors and a green infrastructure led approach to new planned development and tree densification in existing green / recreation space are estimated at around **90 - 110 tonnes CO_2e annually,** an up to around **117% increase on the current situation**.
- Development of **the CNGCID provides some real opportunity to add value to local communities through a wide range of benefits and societal change,** including employment, skills, education, wellbeing, biodiversity and economic equality.

- The study of peak electrical demand has identified that all modelled **developments fall within existing network headroom capacity limits**. There is no urgent need for Active Network Management (ANM) to address electrical grid constraints under the studied conditions.
- The deployment of distributed energy resource (PV and BES) and subsequent coordination of these assets can deliver flexibility objectives to minimise peak load (in cases of future emergence of constraint) and off-setting carbon emissions associated with the grid electrical supply.
- The deployment of PV and BES (at the levels studied) will facilitate net reduction in peak demand by approximately 10% across the existing substations in the Innovation District. Due to the nature of the DHN Heat Pump operating profile and BES available, the DER coordination cannot sufficiently reduce peak demand across a full day of operation. When this is the case, electricity will be supplied from the grid.
- Commercial modelling of the described scenarios requires intervention to strengthen the investment potential of the CNCGID scheme. Specifically:
  - availability of electricity at better price (e.g. negotiated or subsidised PPA) with policy support from local and/or national government. b)
  - availability (extension to the duration) of any rates relief associated to rateable value of district heating network and associated infrastructure.
- The Project has the potential to be attractive to institutional investors for the following reasons:
  - Available existing stable and creditworthy anchor heat (and power) loads.
  - A diversified customer base capable of growing over time within, and beyond, the boundaries of the GCNID
  - A strategy for delivering additional zero carbon heat generation, while transitioning existing CHP generation to optimise the system
  - A holistic, integrated approach to infrastructure which could result in a more economically efficient solution through data-led design, coordination of physical works, infrastructure sharing, stimulating competition and consortium building and future-proofing.

13.2. Key Actions

Four key actions have been recommended.

1. Create a task force for the project.

   Taking the project forward and to create an overall management group that can tackle the other actions identified here. Glasgow City Council and partners involved in the project must assess how they will de-risk the portfolio of projects that form the elements of this overall prospect. The significant infrastructure scale is attractive and ambitious, but it brings with it a challenging programme. Risk will need to be well managed and to reach the positive outcomes, it is recommended that a task force for this work is created. One that is dedicated and resourced to enable the next stage of work. The task force would carry out the following work:

   a. Create an Urban Environmental Improvement Programme

      Initiate and manage an urban environmental improvement programme. This should include analysis of proven best practices and the balance of the need for protection from extremes of temperature, precipitation, strong winds and low daylight in the long winter, while optimising benefits from higher temperatures, daylight and solar energy in the relatively short summer.

   b. Create a communications plan

      Initiate and manage a communications plan to inform the people and businesses of the GCID and to enable inward investors to clearly understand the vision and its delivery potential. Informing stakeholders requires building of capacity, understanding and education. Explaining the roadmap roll out and assistance in initiating actions that individual people, businesses and other GCID users can do to start the development. It is recommended that steps are taken to engage with stakeholders from across the community at the earliest opportunity to begin to define their needs and understand how the programme can support these. Further work is needed to determine who stakeholders are, particularly within the areas of the highest deprivation.

2. Update and adjust the Avenues scope

   The task force should initiate and manage a structured interface with the existing City Deal Avenues Programme including:

   a. Assess and revise the Avenues layout to integrate a whole system approach complimentary to the GCID route map to climate neutrality. This will include the inclusion of High Street as an Avenue with road space designation and delineation of a climate corridor within the design.
   b. The scope of the Avenues project should be assessed to include where appropriate:
      i. Dedicated road space, district energy infrastructure (mechanical, power and control); green canopies; green walls; parklets at scale; and mitigations to climate risks e,g. drainage.
      ii. Adaptions to the assessed climate change related risk of increased flooding, both river and surface flooding.
      iii. Expanded green infrastructure scope that enables a widespread deployment of green walls, green roofs, parklets, enhanced health and well being
3. Create a transportation interface to bring together heat and power planning with transport planning

   The task force should initiate and manage a structured interface with Glasgow City Council transportation planners and development planning teams and District Regeneration Framework teams to ensure the approach to decarbonising transport is implemented consistently across the city through existing transport plans and development frameworks.
4. Create a legal structure

   The task force should establish the appropriate legal structure of an organisation to manage a project of energy network design construction and operation (energy supplier and maintenance) technically and commercially. This shall include.

   a. Funding and initiation of site surveys to determine the nature of services below ground to enable rapid transition and develop understanding of ground conditions and minimise execution contract risk. Such 'early enabling' activities will reduce the risk for design and contracting technical services and subsequently enhance the value of investment. Creating clarity of the pipeline of the development to potential investors.
   b. Preparation of a technical concept design for additional energy centres and the network expansion (including necessary behind the meter works).
   c. Planning and environmental impact appraisal including a detailed whole network decarbonisation plan;
   d. Preparation of a stakeholder engagement plan including identification of potential anchor 'offtakers' and quantification of the scale and timing of firm demand;
   e. Preparation of a high-level financial model.
   f. Confirmation of available public grant funding to support the next stage development activities. Such activities include preparation of a FEED study, a planning application for the additional energy centre(s), survey works, construction procurement and contract negotiations with anchor offtakers and relevant landlords.

14. References

[1] Atkins Ltd, “Climate Neutral (Glasgow City) Innovation District, Baseline Data Report,” University of Strathclyde on behalf of Glasgow City Council, 2021.

[2] IKIGAI, Helena Anderson, “Glasgow CNID - Bankability review (20 August 2021) (002),” IKIGAI, 2021.

[3] Atkins, “5200737-PM-MOM-001 Finance Workshop 21June2021,” Atkins, Helena Anderson on Behalf of Atkins, 2021.

[4] Atkins, “5200737-EG-TCN-001 Climate Neutral Boundary Definition A02,” Atkins, 2021.

[5] Ben Walters, Energy Systems Catapult, “Technical Note to Supplement GIS Datasets,” 2021.

[6] Atkins, “5200737-EN-MEM-003 CNGCID SVP Social Value Plan,” 2021.

[7] Mark Hewlett, , “5200737-EN-MEM-002 Climate resilience Memo,” Atkins, 2021.

[8] Atkins Ltd, “Climate Neutral Distric - Glasgow, Transport Measures,” University of Strathclyde on behalf of Glasgow City Council, 2021.

[9] Atkins, “5200737-PM-WBK-002 Priorisation of CNGCID measures,” 2021.

[10] Atkins SNC-Lavalin, “Climate Neutral GCID Policy Review, 5200737-EG-TCN-003,” in *Climate Neutral Glasgow City Innovation District Feasibility Study*.

[11] Department of Business, Energy & Industrial Strategy, “Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal, Data Tables 1 to19”.

Appendices

Appendix A. Best Practice Urban Environmental Improvements

This section provides a brief review of a selection of best practice ('Green, Car Free City Centres' examples.

Elephant Park, London, UK

£2.3 billion regeneration of Elephant and Castle by Lendlease. A climate positive target was set for the project, in line with the C40 Cities Climate Positive framework. Carbon targets were set that exceed local policy requirements by 30%. An innovative energy solution includes using bio-methane grid injections to offset carbon and connecting 1,000 offsite homes to the CHP system. Retention of existing 120 mature trees from the former Heygate Estate.

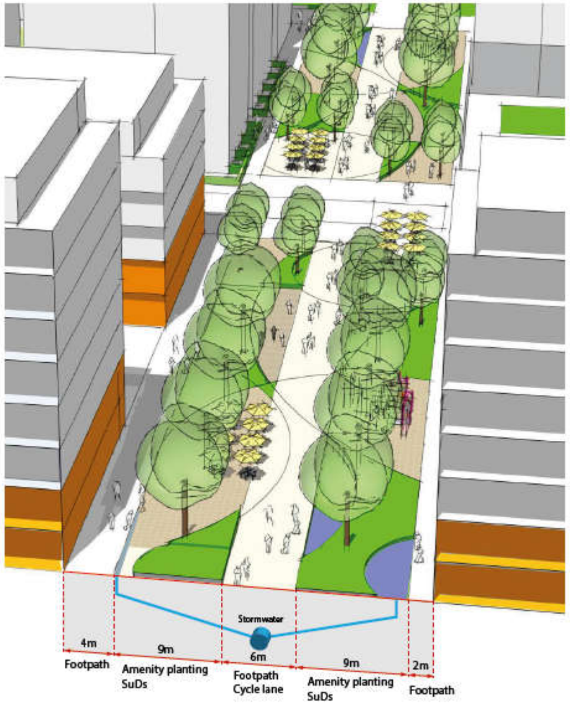
Green street, Elephant Park, London.
Source: Sayer Street, Elephant Park.

Over 1,000 new trees planted both on and offsite forming part of an extensive greening programme. 35% of site comprises accessible open space, with 26% of this green space. The development incorporates extensive green roofs.

Old Oak and Park Royal, London, UK

London and the UK's largest regeneration project, the site includes new stations for High Speed 2 and Crossrail. The 650 ha site includes 135 ha of developable land. Super-high density development is planned: 300-600 dwellings per hectare. Aspirational but deliverable sustainability targets developed to inform local plan, pushing the boundaries, shaping exemplar design, construction. Targets included operational zero carbon, zero waste to landfill and maximising low / zero carbon movement. The proposals for Old Oak include a strong focus high quality streetscapes and public realm. Proposals include multiple green streets to optimise the multi-function benefits of green infrastructure, including green roofs and green walls, and exploring in particular the benefits to both external air quality and noise, as well as overall microclimate, of extensive vegetation cover.

Aerial view of Old Oak indicative development proposals.
Source: Environmental Target Setting Study, Old Oak and Park Royal Development Corporation, 2017.



Old Oak – Indicative green street design.
Source: Environmental Target Setting Study, Old Oak and Park Royal Development Corporation, 2017.

Frankfurt, Germany

The financial capital of Germany, Frankfurt, has developed what are known as 'Luftleitbahnen', or ventilation corridors: stretches of land all around the city where there are no high buildings or large copses of trees to allow cooler air from the surrounding areas to flow downtown. Cool, fresh air is funnelled into a network of 'green islands' in the city: parks, trees, avenues. The city now requires certain new buildings to have a green roof or façade and subsidises the installation of green roofs on private properties. On a sunny day, a traditional black rooftop can reach over 70^{O}C, while a green roof remains below 30^{O}C or less. Water management using porous surfaces to allow for evaporation to cool the streets is also a focus of planning.

Green infrastructure, Liebfrauenstraße,,Frankfurt, Germany.
Source: Five Aspects of People-Friendly Cities, August, 2020.

Green rooftop garden, Frankfurt, Germany.
Source: Euronews, July 2020.

Copenhagen, Denmark

Copenhagen is well known as an environmentally conscious capital, with urban sustainability measures such as district heating which accounts for heating for 65% of the city's homes. The city has been an early pioneer in developing pedestrian and cycling centric mobility. Since 1968 car use has been held constant, while cycle use has been boosted. Foot traffic accounts for 80% of movement in the inner city. In 2012 cycling accounted for 37% of trips to work in the city. Parking has been progressively removed and space given to people.
Bicycles have priority in transport provision, and cycling is the preferred transport mode within the city. City design has the cyclist at forefront of thinking. Ample cycle lanes, raised or clearly marked, are consistently positioned on streets, with protection by kerb side parking. In 2020 the city administration indicated that it is planning to make whole of the 'Medieval Village' central are of Copenhagen car free.

Car free streets, Copenhagen, Denmark.
Source: CPH Post Online, June 2020.

Cycling provision, Copenhagen, Denmark.
Source: Study Tour of Copenhagen, Urbed, December, 2012.

Cycling provision, Copenhagen, Denmark.
Source: Study Tour of Copenhagen, Urbed, December, 2012.

Ghent, Belgium

In 2017 the City of Ghent authority introduced a 'Circulation Plan' which makes it very difficult, if not impossible, to drive through the city from one side to the other. Ghent has been divided into six districts that surround the historic centre and are collectively circled by a ring road, 11km in circumference. Restricting movement across the city is aimed at preventing longer distance traffic from entering and congesting Ghent, but it seems also to have dramatically reduced shorter journeys by vehicles inside the conurbation. The plan has also helped public transport to circulate more freely, with almost no traffic jams in the city centre. The car is no longer the preferred mode of transportation in the city. An extra 2400 extra parking spaces have been created outside of the city, with a dedicated shuttle bus providing access to the centre. And an electric people mover known as a Wandlebus provides free travel within the larger pedestrian only zones to frail persons or those with young children. Cycle infrastructure has also been improved, with more dedicated routes created. Journeys by bike currently account for around 30% of all movements, and the city authority aims to increase this figure to 35% by 2030.

Ghent city centre, Belgium.
Source: Hermesworld Newsroom, September 2019.

Appendix B. Climate Responsive Approach; UK Cities

Plymouth, Devon

This £2.9m project, which is part funded by The European Regional Development Fund, Interreg 2 Seas and the Water Resilient Cities Programme, is part of a wider redevelopment of the Millbay docks area. The development comprises a tree-lined "boulevard" that will link Plymouth city centre to the waterfront and be lined with shops, restaurants, homes and hotels. The existing service road is planned to be widened into a major thoroughfare, demolishing redundant and industrial buildings to clear space for new, modern blocks.

The project, intended to become an attractive and safe walking and cycling route, includes provision for SuDS. Underground tanks will be installed under the highway, capable of holding 240 tonnes of water in case flooding occurs when high rainfall coincides with high tides. Above the tanks will be "rain gardens'" – sunken beds planted with coastal grasses and flowering plants arranged beneath an avenue of trees – which will be irrigated by rain and flood water. The system is being developed in partnership with the Environment Agency and South West Water, as part of the Water Resilient Cities Interreg Programme."

Millbay Boulevard Development, Plymouth.
Source: Business Live, August 2019.

Leeds, West Yorkshire

This £1.7m project comprises the transformation of a Cookridge Street in central Leeds plans to create a new space with seating, greenery and a new cycle path which will be car-free, aimed at maximising green infrastructure and allowing the area to become a hub for outdoor events and activities. The project is part of the continuing Headrow Gateway scheme, which aims to alter the flows of traffic running through the city centre. More than £20m has been invested in the Connecting Leeds schemes with major plans for Westgate, Vicar Lane, New Briggate, Infirmary Street, Park Row and Cookridge Street to improve travel for pedestrians, cyclists and bus passengers.

Cookridge Street, Leeds.
Source: Leeds Live, September 2020.

Manchester City, Greater Manchester

The Great Ancoats Street scheme in central Manchester aims to create a tree-lined boulevard which improves the look and feel of the area for pedestrians and provides a more natural link between the city centre and the rapidly expanding Ancoats and New Islington neighbourhoods. It includes installing new crossing facilities, new road surfacing to reduce noise and more than 70 trees down the central reservation. However, after contractors started work it appeared a number of trees would not be able to be planted in their intended location due to 'unmapped utilities' that have been discovered underneath.

The £9.1m project proved controversial from the outset, with campaigners claiming a lack of consultation with residents and other stakeholders such as cycling groups over the design. Manchester City Council has indicated that locations for 57 of the trees has been confirmed and trial excavations conducted to identify suitable new sites for most of the remaining trees within the boundaries of the project. Putting trees in planters was not considered an option as this requires considerable maintenance and generally lasts only 10 years.

Great Ancoats Street, Manchester.
Source: Manchester Evening News, August 2020.

Appendix C. Prioritisation of Measures; Criterion

C.1. Prioritisation Matrix

An extract from the prioritisation worksheet is given in

				Carbon saving impact (CO2e) to 2030 (CNGCID target)	Embodied energy (CO2e impact) - materials/construction	EPC technical complexity / integration ease	deliverability-technical	deliverability-political, other	Risk -safety, environmental, security, reputational	CAPEX- scale of funding needed	O&M - annual running costs (excl. fuel)	Fundability	Additional benefits	Alignment with existing Supporting Policy/regulation	Future proof - climate resiliance	score	Rank	Comment
Option	**Measure considered**	**applies to**	**Level of Decarbonisation ambition**	carbon reductions over project timescales (to 2030)	aspects are required in terms of construction (e.g.	y? Smoothness to install/scale up (e.g.	achieveable by 2030? Infastructure challenges, planning	complexity, unclear boundary definition between	potential impact to People and Environment of	investment required; public/ private to consumer	operate annually (excluding fuel); maintenanc	ss for funding, based on UK examples	e.g. fuel poverty alleviation, health and wellbeing	existing support framework to achieve? E.g. policy,	proposed measure take consideration of future climate? e.g severe		**#**	
1	ESC measures modelled; Building energy material efficiency improvements package, includes: *internal insulation, double glazed, loft insulation to max, smart heating controls, fixed lighting demand reduction (-24%), appliance demand reduction (19.5%)*	Building Performance	Transformational	3	3	2	3	2	3	2	3	3	3	3	3	33	**2**	These measures are easy relative wins, and key enablers to scenarios
2a	H2 (up to 20% blend in grid) + local electrification	Energy supply (Scenario 1)	Transformational	2	3	2	3	1	2	2	3	2	2	1	2	25	**8**	some benefit, but externally influenced, and
2b	H2 (>20% blend in grid) + local electrification	Energy supply (Scenario 1)	Leading the way	1	2	1	1	1	2	1	2	2	2	1	2	18	**10**	within project timeframe not attractive
2c	DHN 'anchor loads' network adoption	Energy supply (Scenario 2)	Transformational	3	2	2	3	3	3	1	2	3	3	2	2	29	**7**	
2d	DHN; full network adoption	Energy supply (Scenario 2)	Leading the way	3	2	2	2	2	2	1	2	2	3	2	2	25	**8**	not without challenge, but offers pathway to
3a	Transport measures (achieve 25% reduction from transport baseline); *active modes, public transport upgrades, demand management, digital hub, EV and charging, shared transport,*	Transport	Transformational	1	3	3	3	3	3	2	2	3	3	3	3	32	**4**	scoring reveals these are easy wins, although
3b	Transport measures; similar measures but increased roll out, and uptake achieving 35% reduction from baseline	Transport	Leading the way	1	3	3	3	2	3	2	2	3	3	3	3	31	**5**	scoring reveals these are easy wins, although
4	Virtual power plant (PV and BESS coordination)	Energy supply/ Flexibility		2	3	3	3	3	3	3	3	2	2	1	3	31	**5**	can offer lower grid intensity, and flexibilty o
5a	Environmental measures; green space, allotments, derelict land use	Environmental	Transformational	1	3	3	3	3	3	3	3	3	3	3	3	34	**1**	although modest rewards, the cost and impac
5b	Environmental measures; 'Transformational case' but with increased action, inclusion vertical gardens	Environmental	Leading the way	1	3	3	3	3	2	3	3	3	3	3	3	33	**2**	

Figure C-1 [9], which indicates the order of merit that the measures should be implemented in. For some packages of measures a "Transformational" and "Leading the Way" level of decarbonisation ambition is given.

Option	Measure considered	applies to	Level of Decarbonisation ambition	Carbon saving impact (CO2e) to 2030 (CNGCID target)	Embodded energy (CO2e impact) - materials/construction	EPC technical complexity / integration ease	deliverability-technical	deliverability-political, other	Risk -safety, environmental, security, reputational	CAPEX- scale of funding needed	O&M - annual running costs (excl. fuel)	Fundability	Additional benefits	Alignment with existing Supporting Policy/regulation	Future proof - climate resiliance		score	Rank	Comment
				carbon reductions over project timescales (to 2030)	aspects are required in terms of construction (e.g.	y? Smoothness to install/scale up (e.g.	achieveable by 2030? Infastructure challenges, planning	complexity, unclear boundary definition between	potential impact to People and Environment of	investment required; public/ private to consumer	operate annually (excluding fuel); maintenanc	ss for funding, based on UK examples	e.g. fuel poverty alleviation, health and wellbeing	existing support framework to achieve? E.g. policy,	proposed measure take consideration of future climate? e.g severe			#	
1	ESC measures modelled; Building energy material efficiency improvements package, includes: *internal insulation, double glazed, loft insulation to max, smart heating controls, fixed lighting demand reduction (-24%), appliance demand reduction (19.5%)*	Building Performance	Transformational	3	3	2	3	2	3	2	3	3	3	3	3		33	**2**	These measures are easy relative wins, and key enablers to scenarios
2a	H2 (up to 20% blend in grid) + local electrification	Energy supply (Scenario 1)	Transformational	2	3	2	3	1	2	2	3	2	2	1	2		25	**8**	some benefit, but externally influenced, and
2b	H2 (>20% blend in grid) + local electrification	Energy supply (Scenario 1)	Leading the way	1	2	1	1	1	2	1	2	2	2	1	2		18	**10**	within project timeframe not attractive
2c	DHN 'anchor loads' network adoption	Energy supply (Scenario 2)	Transformational	3	2	2	3	3	3	1	2	3	3	2	2		29	**7**	
2d	DHN; full network adoption	Energy supply (Scenario 2)	Leading the way	3	2	2	2	2	2	1	2	2	3	2	2		25	**8**	not without challenge, but offers pathway to
3a	Transport measures (achieve 25% reduction from transport baseline); *active modes, public transport upgrades, demand management, digital hub, EV and charging, shared transport,*	Transport	Transformational	1	3	3	3	3	3	2	2	3	3	3	3		32	**4**	scoring reveals these are easy wins, although
3b	Transport measures; similar measures but increased roll out, and uptake achieving 35% reduction from baseline	Transport	Leading the way	1	3	3	3	2	3	2	2	3	3	3	3		31	**5**	scoring reveals these are easy wins, although
4	Virtual power plant (PV and BESS coordination)	Energy supply/ Flexibility		2	3	3	3	3	3	3	3	2	2	1	3		31	**5**	can offer lower grid intensity, and flexibilty o
5a	Environmental measures; green space, allotments, derelict land use	Environmental	Transformational	1	3	3	3	3	3	3	3	3	3	3	3		34	**1**	although modest rewards, the cost and impac
5b	Environmental measures; 'Transformational case' but with increased action, inclusion vertical gardens	Environmental	Leading the way	1	3	3	3	3	2	3	3	3	3	3	3		33	**2**	

Figure C-1 - Prioritisation Matrix

C.2. Criterion

The Criterion used to assess the packages of Measures applied to the CNGCID are given below. These were assessed on a Red-Amber-Green (RAG) basis to indicate visually the measures which should be prioritised, and which offer relatively few technical or commercial challenges to implementation:

Table C-1 - Prioritisation Matrix; Assessment Criterion

			Red -Disadvantageous	Amber - Neutral	Green - Advantageous
ID #	**Requirement Criteria**	**Description**	**1**	**2**	**3**
1	Carbon saving impact (CO2e) to 2030 (CNGCID target)	Impact on carbon reductions over project timescales (to 2030)	Some savings, but pathway to net zero extends beyond 2030	Contributor, but not on critical path to achieving 2030 target	Significant contributor (>20%) to Carbon neutral 2030 target, critical path
2	Emboddied energy (CO2e impact) - materials/construction	What other aspects are required in terms of construction (e.g. concrete)	Significant impact on carbon footprint; e.g. rare matrials, high carbon materials (concrete, plastics)	Some impact, but can be minimised through procurement choices	Little / no impact to carbon footprint
3	EPC technical complexity / integration ease	Compatibility? Smoothness to install/scale up (e.g. historic buildings, working at height)	FOAK construction process. Significant modification/adaption needed per building basis.	Less certainty with some elements a UK FOAK. Measures may need adapted to each install case.	Established EPC process, risks understood and managed. Measures has wide compatibility
4	deliverability-technical	technically achieveable by 2030? Infastructure challenges, planning implications, complexity	Several external influences, outwith project control	Risk of missing project timeframe due to external factors	Likely to meet project timeframe; within project responsibility
5	deliverability-political, other	Stakeholder complexity, unclear boundary definition between councils, businesses and ownership	Several external influences, outwith project control	Risk of missing project timeframe due to external factors	Likely to meet project timeframe; within project responsibility
6	Risk -safety, environmental, security, reputational	What is potential impact to People and Environment of measure(s)	Potential for HSE impact outside site boundary - public and local impact	Potential for HSE impact within site boundary, or localised.	Little/None
7	CAPEX- scale of funding needed	Level of investment required; public/ private to consumer led models or incentives	Significant investment required (£10M+) multiple funding routes to be explored	Moderate Investment required (mix of public/private)	Minor investment required to enact storage option
8	O&M - annual running costs (excl. fuel)	Costs to operate annually (excluding fuel); maintenance, servicing	Significant O&M required; frequent or annual outage	Moderate O&M required; frequent 1+ person	Minor O&M required, infrequent
9	Fundability	Attractiveness for funding, based on UK examples or existing known finance support (e.g. grants, loans)	No clear on who pays for it, and pathway to overcome this	Less certainty on funding route	Several successful models exist, known route to funding
10	Additional benefits	e.g. fuel poverty alleviation, health and wellbeing	limited known additional benefits, or negative influence	few additional benefits or not strong project drivers	several additional benefits, these are strong project drivers
11	Alignment with existing Supporting Policy/regulation	Is there an existing support framework to achieve? E.g. policy, regulation, funding incentives	Measures are either novel or an existing support is unknown/immature	measures proposed include some fully supported and some immature	measures are well aligned with known key support mechanisms
12	Future proof - climate resiliance	Does the proposed measure take consideration of future climate? e.g severe weather	high impact. Measures may become unsuitable for future climate.	some impact to measures proposed with future climate case, but can be mitigated	low impact to measures proposed with future climate case, or high flexbility by design or unaffected

Appendix D. DHN routing

D.1. Anchor Loads DHN, Phase 1 construction

The following routing was agreed upon through workshop sessions and one-to-one routing refinement with key stakeholders. It is however still preliminary routing at this stage for the feasibility study and likely to change significantly in final design. The routing was provided by partners COMSOF using leading DHN design software.

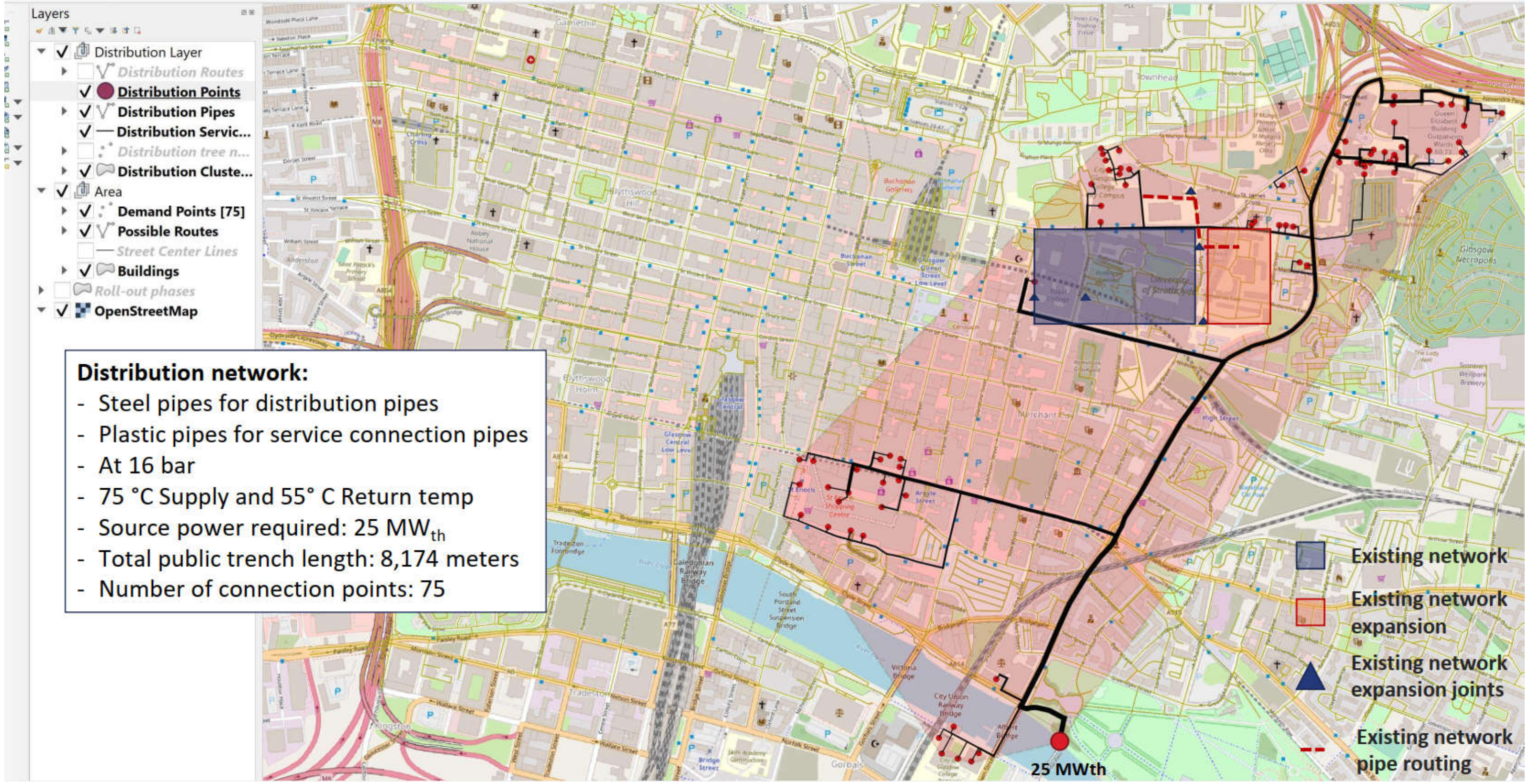


Figure D-1 - Phase 1; Anchor loads preliminary DHN routing

D.2. Full 100% DHN, Phase 2 construction

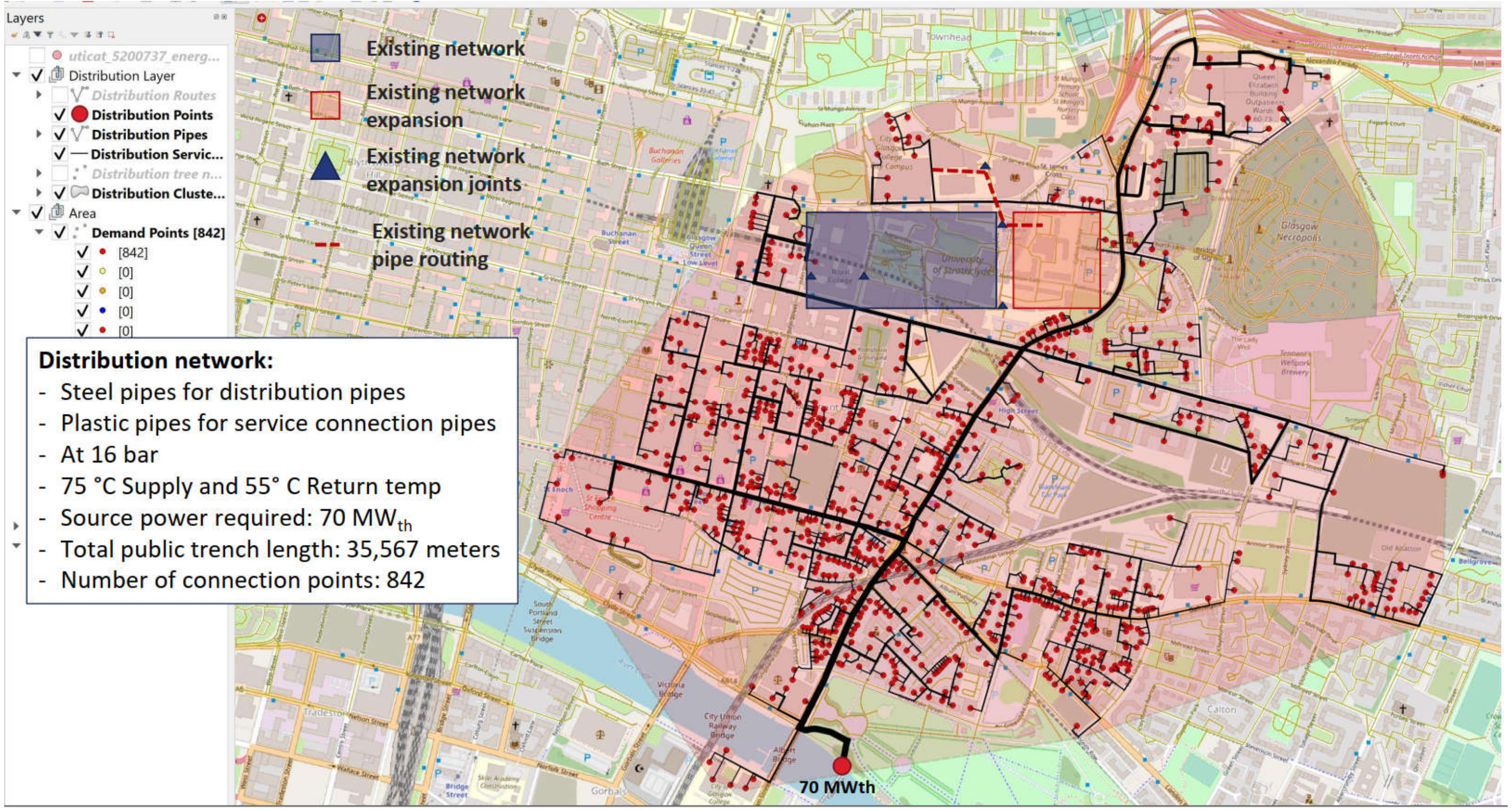


Figure D-2 - Phase 2; 100% DHN preliminary routing

Ewan Murray
Atkins Limited
8 Mallard Way
Strathclyde Business Park
Bellshill
North Lanarkshire
ML4 3BF

ewan.murray@atkinsglobal.com

+44 (0)7815 243668