Technical Note

Project:	Feasibility Study: Carbon Neutral Glasgow City Innovation District (CNGCID)		
Subject:	Methodology		
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Date:	18/08/2020	Revision:	A00

Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
A00	DRAFT	MG	JE	CE	MG	20/08/2020
A01	First Issue	MG	JE	CE	MG	21/08/2020

Client signoff

Client	University of Strathclyde
Project	Feasibility Study: Carbon Neutral Glasgow City Innovation District (CNGCID)
Project No.	SN0211143
Client signature / date	R. Yarr

1. Introduction

The purpose of this technical note is to inform stakeholders of the technical feasibility study of Carbon Neutral Glasgow City Innovation District (CNGCID) of the methodology that will be followed. In addition, this technical note includes indication of where additional value can be added with data from stakeholders.

The methodology is tailored such that the University of Strathclyde in partnership with Glasgow City Council and partners can work to deliver the CNGCID study to ensure key aim and outputs can be achieved. The drivers underpinning the delivery philosophy are:

- **a whole system approach**
- **partnership & collaboration**
- **community focus**
- **creating a sustainable long-term plan**
- **maximising learning, teaching and research opportunities**

2. Approach

The feasibility team will be led by Atkins (who take the role of Systems Architect) and supported by industry subject matter experts (SMEs) from Energy Systems Catapult, Star Renewable Energy, Smarter Grid Solutions and Ikigai Capital. In our role as Systems Architect we will undertake specific technical and economic assessment of solutions including heat, power, transport, climate adaptation, wellbeing and social inclusion. Our fundamental responsibility as System Architect is to keep focussed on providing a “at scale” routemap to enable the climate neutral strategy.

As the Systems Architect Atkins will work collaboratively with the University, Glasgow City Council and the aforementioned SMEs. However, the input from key Glasgow businesses, organisations and the community will add value and relevance to the study. A Steering Group will subsequently be set up to consult as we progress through the study. The steering group will have the opportunity to provide data as well as be informed at key stages throughout the work and be given the opportunity to comment on our analysis, findings and recommendations.

3. Methodology

The methodology to undertake a feasibility study into a Carbon Neutral Glasgow City Innovation District (CNGCID) is laid out in Figure 3-1.

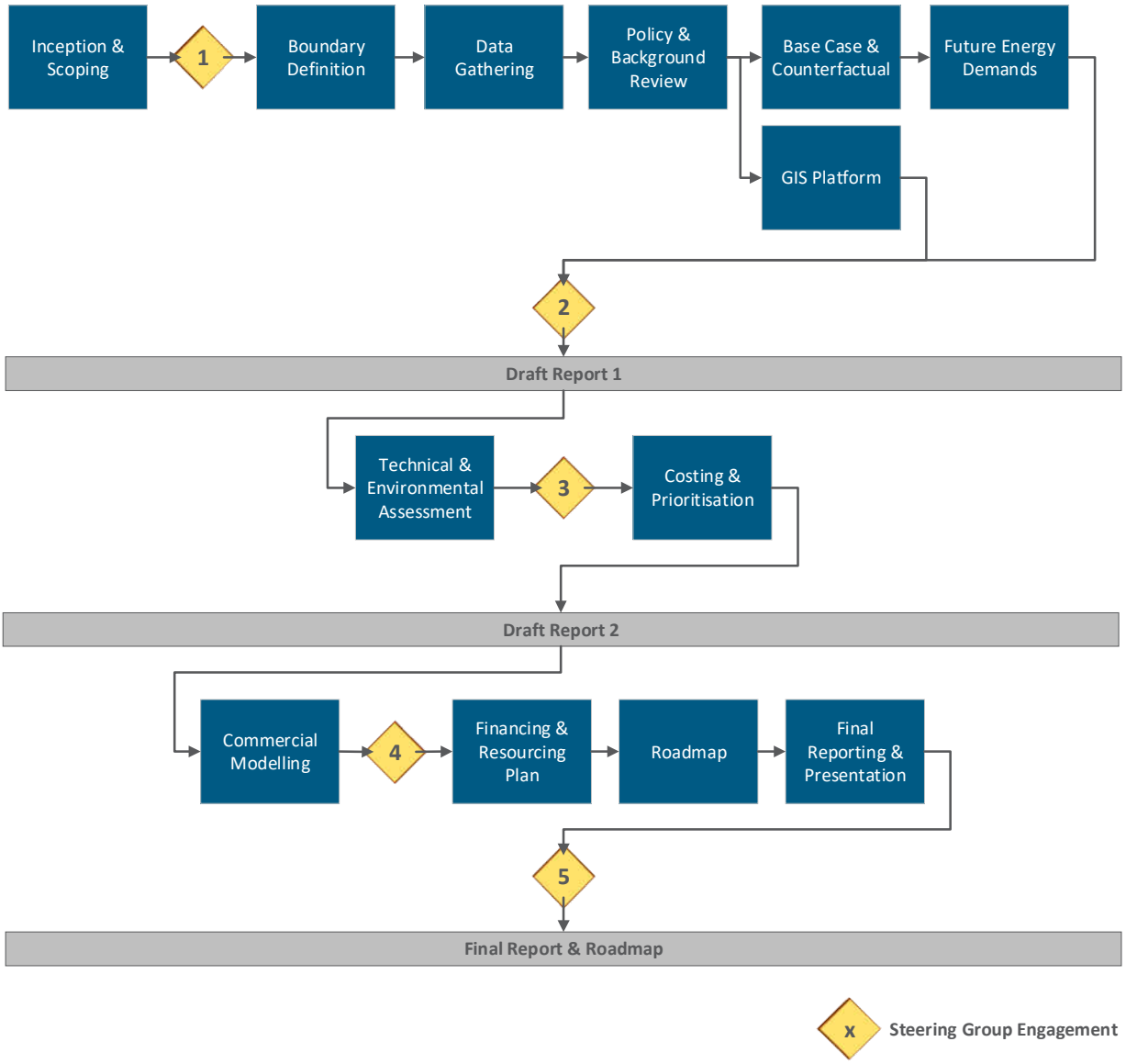

Figure 3-1 - Methodology Diagram

A staged approach allowing engagement with invested parties, stakeholders and the steering group allows a collaborative delivery culture and a final proposed route-map that we believe will be relevant, achievable and bought into by the project stakeholders.

The individual tasks and outputs are summarised below:

Task 1: Inception and Scoping

To ensure all parties understand and agree the scope, timescales, deliverables and delivery plan. Including items such as critical path datasets or information to enable the study.

Outputs:

1. Programme
2. Inception meeting Minutes of Meeting
3. Communications Plan

Task 2: Defining Study Boundary (the "redline")

Defining the study boundary area at the outset of a project ensures:

- Clarity for stakeholders for geographical inclusion
- Carbon accounting within the project can be accurately assessed
- the boundaries are clear for the technical, environmental, social and economic assessments
- identification of wider linkages out with the defined study boundary area are clear
- Consideration extent of Distribution Network Operator (DNO) /utility infrastructure, Glasgow city council boundaries, anchor load locations for district heating, existing green spaces, adjoining communications, data set availability.

Outputs:

4. Technical Note: Study Boundary Area

Task 3: Data gathering

Existing data and information on heat, power, air quality, noise, flood risk, temperature, rainfall, greenspace etc is required to help us build up overarching Geographic Information Systems (GIS) map for the study area. GIS is a system designed to capture, store, manipulate, analyse, manage, and present spatial or geographic data. In addition, background reports, future development plans and economic initiatives will be required to assist the analysis and options selection.
Crucially a significant volume of this data is requested from the University, Glasgow City Council and steering group members steering group.

Outputs:

5. Request for Information (RFIs)

Task 4: Policy and Background Review

To assist the study a review of the following policies will be completed:

- Local policy
- Regional policy
- National policy
- International policy
- Emerging guidance and standards
- Other local or related initiatives e.g. LHEES, Ruggedised Smart Streets development

The steering group should ensure new or emerging initiatives are informed and subsequently captured

Outputs:

6. Technical Note: Policies

Task 5: Base Case and Counterfactual

Captured in the GIS map, a base case for carbon emissions (or 'counterfactual') of the current district will be produced, such that the savings associated with the solutions and strategies being proposed within the route map are measurable. This will primarily include energy demands (heat, power, cooling) and current carbon emissions, however current situation with respect to existing green spaces, biodiversity measures and any social initiatives that currently exist will also be included. Data from DNO and utility information, planning data, information on existing renewable energy generation and other salient information that will allow us to have a full picture before commencing the assessment.

Outputs:

7. GIS base case dataset
8. Technical Note: Base Case (counterfactuals)

Task 6: Future Energy Demands

Likely future energy demands across the study area will inform the levels of energy generation, distribution, storage and supply required to provide the heating, cooling and power needs for users, including transportation. This stage will:

- Consider all available future development information to establish the likely demand increases
- Assess changes to energy use type (e.g. electrification of heat)
- Consider the role of energy efficiency measures to reduce demand for heating and cooling
- Review the ways our buildings are used, to see whether changes in operation (e.g. time shifting of loads) can reduce peak demands
- Review the increase in electrical demand due to electric vehicle charging

A holistic assessment of this future demand, from a **whole system approach is crucial**. For example, we will consider the likely power demands from the electrification of heat, coupled with electrification of transport, to understand the overall increase in power demand.

Outputs:

9. Technical Note: Energy Demand Profiles

Task 7: Services Database GIS Solutions Library Platform

Implementation of a bespoke, intuitive and user friendly WebGIS platform (web-based data visualisation and analysis tool) that enables project team members, stakeholders and/or the public to make and understand crucial project decisions and inform city plans through the integration of scheme data onto a single platform

Outputs:

10. WebGIS Platform

DRAFT REPORT 1

Findings to date (summary of technical notes) and proposed report structure.

Task 8: Technical and Environmental Assessment

Assessment and review of the technologies, solutions and strategies that have the combined potential to create a 100% renewable energy system for the carbon neutral district.

The assessment will consider a whole system approach including urban planning, social inclusion, biodiversity strategies, climate resilience strategies, future proofing strategies and other 'nature based' solutions and will be completed by a wide team of experts including: energy, transport, environmental consultants, climate change strategists and industry SMEs.

Using the GIS model this assessment will run a number of specific assessments for each specific solution. Depending on the area, this could include detailed energy modelling and technology assessment for carbon emissions, or environmental assessment techniques for flood risk, air quality, carbon sequestration and biodiversity gain. For each solution a central focus will be the ability to reduce emissions while at the same time achieve multiple environmental and social benefits and therefore contribute to a whole system road map strategy.

The specific reviews that will be conducted at this stage include

- Renewable Energy Systems
- Smart Grid System
- Green fuel cell
- Solar EV and Bike hub
- Climate neutral space along pedestrianized George/ Montrose/ High St
- Climate Corridors for energy/ transport/ climate adaptation (Collaboratively delivered with Climate Ready Clyde, GCV Green Network Partnership, MGSDP and Central Scotland Green Network Trust)
- Heat Pumps
- District Energy Networks
- Climate change risk assessment and vulnerability assessment and adaptation plan

A more detailed approach is for each review is included within Appendix A

Outputs:

11. Renewable Energy System (LEAR): current energy assets and demand in the local area
12. Renewable Energy System (LEAR): impact of planned growth and other assumed energy system change on the existing energy system
13. Technical Note: 100% renewable Energy System
14. Technical Note: Smart Grid System
15. Technical Note: Green Fuel Cell
16. Technical Note: Solar EV and bike hub
17. Technical Note: Climate neutral space along pedestrianized George/ Montrose/ High St
18. Technical Note: Climate Corridors for energy/ transport/ climate adaptation (Collaboratively delivered with Climate Ready Clyde, GCV Green Network Partnership, MGSDP and Central Scotland Green Network Trust)
19. Technical Note: Heat Pumps
20. Technical Note: District Energy Networks
21. Risk Assessments: Climate change risk assessment and vulnerability assessment and adaptation plan
22. Technical Note: Climate change risk assessment and vulnerability assessment and adaptation plan

Task 9: Social Value Plan

A specific social value review for the Glasgow city district involves looking beyond the price of each individual contract and considering what the collective benefit to a community is when a public body chooses to award a contract with an aim to:

- Develop innovative ways to deliver services which directly create social value
- Create additional value
- Achieve efficiencies

Outputs:

23. Technical Note: Social Value Plan

Task 10: Soft Market Testing, Costing and Prioritisation

High level capital (CAPEX) and operational (OPEX) costing for the solutions proposed in Task 8. based on current market best practice and market rates, ensuring our proposals are 'real world and Atkins and delivery partners' internal cost databases,

An overall quantitative ranking and prioritisation matrix will consider a range of key factors to enable the shortlisting of solutions that will be taken forward for consideration under the commercial modelling.

Outputs:

24. Cost Model
25. Prioritisation Matrix
26. Technical Note: Cost and Prioritisation

DRAFT REPORT 2

In addition to draft report 1, this report will include prioritised, preferred and ranked solutions

Task 12: Commercial Modelling

An overall 'Techno-Economic' model for the study. This model combines technical calculations (e.g. loads and outputs) with capital and operational costs generated under Task 11. The key benefit is joined up analysis between the technical solutions and their associated economics and, importantly, results in an iterative analysis of optimal overall solutions. The modelling includes:

- CAPEX & OPEX modelling
- Cash Flow modelling
- Metrics modelling e.g. (£/tCO_2e saved)
- Iterations to provide best blended solution

Outputs:

27. Technical Note: Commercial Modelling

Task 13: Finance and Resourcing Plan

Bridging the gap between investors, consumers and the innovative technology necessary to create bankable projects a finance and resourcing plan wi9ll be developed to inform how the commercial model for the delivery and management of the Climate Innovation District could be managed This will include soft market testing with investors and advice on how the project could be funded with multiple partners.

Outputs:

28. Technical Note: Finance and resourcing plan

Task 14: Route-map

capturing the overall strategy as a ‘route map’ infographic. This is a simple and effective way to represent the proposed timings, solutions and interdependencies, such that non-technical stakeholders can visualise and understand the proposals.

Outputs:

29. Route-map infographic

Task 15: Reporting & Presentation

Having produced Technical Notes, draft reports and engaged the steering group and other stakeholders throughout the study, everyone will understand the proposed strategy and the rationale behind it. The final report is a single point capture of this strategy and a record of our overall output with ‘no surprises’ due to ongoing engagement throughout the study.

The report will clearly define a set of next steps to allow the project to progress towards implementation. This will include the overall project risk register highlighting key risks and associated mitigation measures.

After comments have been received a final presentation of the study will be presented, to the project steering group and wider stakeholders.

Outputs:

30. Final Report
31. Final Presentation

Following the final presentation, we will be please to support the University and partners with advice or clarifications that would support you consult with a range of stakeholders. The subject matter experts from Atkins and our wider sub-consultancy team will all be available to provide further advice or guidance on their specific areas of expertise.

Appendix A. Technical and Environmental Assessment Reviews

Renewable Energy System

Development of a 100% renewable energy system requires a good understanding of the existing energy assets i.e. annual and peak energy demands, social metrics, electric vehicles (EV) chargepoints etc. We will undertake an assessment of existing data and projects within the region including the Glasgow Heat Map work, Gorbals Heat Pump; Drygate Heat Pump and CHP solution; Collegelands geothermal concept, and from Glasgow's current city development plan and the University of Strathclyde's development plan, LHEES programme and other sources.

We will generate two Local Energy Asset Representation (LEAR) reports for the project area using the datasets listed above augmented by publicly available data such as building data from Scottish Housing Survey, spatial maps from Ordnance Survey, Office of National Statistics, BEIS etc, to enable a fast and effective means of building a data-driven whole system picture of the area today. The first report will provide an overview of current energy assets and demand in the local area. The second will consider the impact of planned growth and other assumed energy system change on the existing energy system, highlighting constraints and key considerations.

This will be according to information provided by Glasgow on plans for current growth and the future technologies identified by the project. This provides a base set of evidence to inform system design and understanding of energy related emissions from which to develop more detailed decarbonisation plans, and would typically involve:

- Synthesising current electricity network layout and gas supplies
- Estimating current feeder capacities (and substation capacities if not provided by DNO)
- Defining key loads connected to different network assets
- Defining embedded generation connected to different network assets
- Estimating demand curves for connected key loads for different characteristic days (e.g. winter peak, summer weekend etc.)
- Predicting unconstrained generation curves for embedded generation for different characteristic days
- Aggregating demand and supply curves by network asset to represent the current situation

Based on a good understanding of the existing energy infrastructure and planned activities, we will investigate options to deliver a 100% renewable energy system delivering power, heat, and supporting activities within the district and the associated cost and investment needs in key infrastructure and technologies for each local areas using tools such as **EnergyPath Networks** and our supporting **Data Platform**. This will involve:

- Creation of a 100% renewable, whole energy system scenario that assesses key considerations such as the electrification of vehicles and decarbonisation of heat
- Development of a plausible representation of the area's existing and future energy system through the production of two LEAR representations.

The output of this stage will be a specific Technical Note, plus supporting models.

Smart Grid System

Smarter Grid Solutions will use their unparalleled knowledge, skills and experience – particularly of the local Glasgow area – to undertake the following tasks.

Active Network Management (ANM) Study
Through engagement with SP Energy Networks, we will review the local electrical grid capacity in the area and identify the nature and severity of grid constraints that may limit further development of generation (e.g. renewables) or electrical demand (e.g. EV charging, electrical heating technologies). From review of publically-available information, we are already aware of fault-level constraint issues on the HV network in Glasgow City Centre.

The review will explore the trigger of grid constraints (e.g. thermal capacity, fault level), the affected voltage levels (e.g. scale of constraint) and derive a high-level overview of hosting capacity headroom through discussion with SP Energy networks. These critical factors will define the requirement for Active Network Management solutions to address grid constraints and avoid the need for costly grid reinforcement.

Virtual Power Plant (VPP) Study
Building on the understanding of grid constraints (ANM study task), opportunity for deployment of ESS and the existing or in-development renewable generation, we will present the value case for coordination across these different energy assets. Through the advanced monitoring, control and optimisation of these assets, a number of value-adding grid and market integration use cases will be demonstrated across the carbon-neutral zone. This will reflect the DER fleet operation, grid interaction and market participation in Virtual Power Plant (VPP) operating models.

Firstly, we will present the different use cases that can be delivered through coordination of the energy assets. It will present a whole-system view of use cases, ensuring the value drivers are not only focused on commercial/financial cases, but also include the implications for wider energy (e.g. heat) and transport (electric vehicles). Each of the critical VPP use cases will be presented in a manner specific to the city area studied, aligning with the technologies and energy assets identified throughout the study.

We will then present a high-level technical architecture for how the VPP will be achieved, presenting the component parts, and the interfaces between technological elements. We will draw from our experience in the study, specification and design of solutions to coordinate distributed energy assets for delivery of complex optimal use cases.

Integration of Distributed Energy Resource (DER) Study
We will review the outputs from the wider area assessment and analyse the opportunity for installation of grid-scale (Multi-MW) energy storage system (ESS) at the University campus. The assessment will evaluate characteristics such as ESS technology (NaS, Li-Ion, Redox flow), device footprint; sizing option and CAPEX/OPEX to present a shortlist of options for deployment.

The use of the ANM and VPP capabilities from the other sub-tasks will be embedded in the qualitative presentation of value streams of ESS and opportunities for research and innovation applications.

The assessment of ESS (and any renewable generation deployments) will identify the opportunity to off-set any grid constraints (as identified in ANM study). Where the existence of grid constraints may restrict the value proposition of ESS or renewables, this will be identified and the implications for delivery of use cases.

The overall output of the Smart Grid System assessment will be a Technical Note.

Green fuel cell

Our assessment regarding the potential fuel cell deployment will be grounded in first understanding the site needs and intended application, in order to inform a feasibility study and an evaluation exercise seeking to identify the optimal fuel cell type and size, and the best means of approaching its integration. This analysis would consider:

- Desired application and expected demand. This will include understanding whether the requirement is solely for electricity supply or whether combined heat and power supply would be preferred, and what the site context is (how much space is available, and where the fuel cell would be sited). In addition, it would be useful to understand if this application has a wider strategic purpose (e.g. demonstrating a new technology development) or whether it should be assessed on its own merits only;
- Potential and desired fuel source, firstly focussing on establishing the availability of hydrogen supply, either produced locally or if relevant, via existing campus hydrogen supply networks. Consideration would also be given to high efficiency fuel-flexible fuel cells which may be expected to operate using natural gas in the first instance;
- Thus, the type of fuel cell that is most appropriate to the site, bearing in mind different fuel requirements, thermal outputs and physical space footprints of the different variants available;
- Based on the anticipated demand and type of fuel cell selected, the size of fuel cell stack required;
- How the fuel cell would integrate into the site and the wider energy system based on the above, including whether the fuel cell contributes to the objectives of the whole system, or whether other technologies could provide similar services in a way which is more beneficial from a whole systems perspective.

Anticipated inputs into this analysis therefore primarily focus on site requirements and specifications, as well as anticipated demand data and an understanding of fuel availability.

We would anticipate conducting preliminary evaluation based on light touch analysis of those variables prior to sense checking our proposed solution with relevant stakeholders ahead of developing the full feasibility assessment.

The overall output of the Green Fuel Cell assessment will be a Technical Note.

Solar EV and e-bike hub

This feasibility work will help to define the best locations for a solar-powered EV and E-bike hub within the university campus and wider district based on the current and potential demand for electromobility within the district. To develop this task, we will apply a methodology based on the following three workstreams:

- Identification of current and future electromobility demand within the district
- Assessment of hub location, the number of chargers and specifications
- Techno feasibility assessment of solar PV supply with co-located battery storage

We are aware that the University of Strathclyde has an existing electric vehicle (EV) pool car fleet and associated charging infrastructure, and that the University's John Anderson campus also hosts two EVs that are available to members of the public via the Co-wheels car club[1]. We are also mindful of the proximity to the University of Strathclyde campus of e-bike charging hubs, installed by Glasgow City Council in 2018 as part of its broader bicycle sharing scheme[2]. We propose to establish a baseline understanding of user uptake and engagement with these services, to contextualise our work in evaluating potential future demand for EV and e-bike services within the campus and the surrounding areas within the Glasgow City Innovation District.

This assessment will be developed as part of ITT Specification Task 3 of the project, consistent in identifying the active travel component needed to make the district a net-zero exemplar. We will consider the current buildings and the planned future large-scale developments within the scope of the analysis, such as hotels and commercial buildings.

We will then identify the advantageous locations within the district area to install hubs for EV and E-bikes chargers and the size of the charging infrastructure based on current market knowledge. This will include:

- Identification of technical characteristics and costs of shelters, vehicle chargers and associated software packages needed for the financial assessment.
- Definition of the type of vehicle chargers and proposition of uptake of the charging infrastructure and systems installed based on potential growth of the electromobility demand and the trade-off between few centralised hubs or multiple small hubs distributed within the area of the district.
- Identification of the ability to connect to the grid at different locations and any constraints on capacity/peak charging.

With an in house excel based model we will determine the size of solar PV and Battery storage required to cost-effectively balance supply and demand in each hub based on the utilisation patterns of the vehicle users and the charging infrastructure characteristics. Therefore, the economic case for solar PV collocated with batteries will be developed for each charging hub identified. The analysis will consider:

- Capital cost and Operating cost (including maintenance/repair, and electricity costs in case of the need for using the grid for back-up).
- Revenue generation potential based on anticipated usage over time.
- Payback period of solar PV and Battery storage (i.e. how long it will take to generate an amount of revenue equivalent to the capital investment).
- Also, we will consider within the assessment the analysis of opportunities of using any idle capacity to provide grid services to Scottish Power.

[1] https://www.strath.ac.uk/sustainablestrathclyde/sustainabletravel/electric_cars/

[2] https://www.glasgow.gov.uk/article/23276/eBikes-Get-Ready-To-Go-in-Glasgow

This assessment will include a high-level indication of the solar PV and battery technology requirement (type, chemistry, power, energy) given the dispatch characteristics required to minimise the utilisation of the grid to supply the charging infrastructure. Within the analysis, we will also consider the installation solar PV and batteries on existing e-bike charging hubs installed by Glasgow City Council in 2018 within the area of the district as part of its broader bicycle sharing scheme e-bike.

Finally, the findings of this activity regarding the number and costs of EV and e-bike chargers, solar PV and battery storage infrastructure will feed into the overall financial analysis and broader stakeholder engagement of the project.

The overall output of the Solar EV and e-bike hub assessment will be a Technical Note.

Climate neutral space along pedestrianized George/ Montrose/ High St

Pedestrian friendly areas are safe and convenient for walking and cycling, not only reducing CO2 emissions, but improving human health through greater physical exercise, better air quality and less noise. They also provide space for 'nature related' interventions.

As part of this task, we'll consider the creation of green horizontal and vertical spaces in the pedestrianized areas. Street trees are an important component for healthy and biodiversity positive greenspaces. They provide multiple benefits which include absorption of air pollutants and carbon dioxide and release of oxygen; provide shade and protection from the sun; reduce the heat island effect; slow wind speed; provide habitats for birds and other wildlife; slow down urban water run-off after a storm, reducing likelihood of flooding; visually soften the hard urban form; and add seasonal change and interest to streets.

The installation of green living walls and green roofs will also be considered as they provide similar benefits to those quoted for trees and in addition to providing the building with an extra layer of insulation and in that way cut down on energy loss and help to keep homes cool in summer.

A Technical Note will be produced to summarise our finding, identifying how these initiatives can be integrated with the wider energy, transport and social solutions being developed across the study.

Climate Corridors for energy/ transport/ climate adaptation

Working in partnership with Climate Ready Clyde, GCV Green Network Partnership, MGSDP and Central Scotland Green Network Trust, we'll consider the opportunity for creation of a series of 'climate corridors' which integrate energy, transport and climate adaptation (such as on High Street and George Street, integrating with the City Deal Avenues and Places for Everyone works on both these streets), which incorporate service corridors for heat and power and climate adaptation solutions.

The corridors will integrate many of the 'nature based' concepts considered for the pedestrianised areas discussed above and other adaptation solutions into these 'climate corridors'.

In addition, given that high density areas create increased surface water run-off, which may exacerbate flood risk during heavy storms, one of the most effective ways to address this is to maximise multifunctional green infrastructure. A wide variety of Sustainable drainage systems

(SuDS) use infiltration and attenuation to manage the quantity and quality of storm runoff generated during rainfall and these will be investigated. In particular, we'll investigate the optimal deployment of green roofs and SuDS to reduce indoor overheating and flood risk.

The overall output of the climate corridor assessment will be a Technical Note.

Heat Pumps

The 'Weegie Board' is a loose collaboration drawing on the skills of Star Renewable Energy in heat pumps, Comsof in network modelling and Mini-Bems in Building interface and operational optimization.

Whilst admittedly an odd name, it reflects that the three companies have a shared passion to see district heating deployed across the world in cities but recognise that individually their skillset is only part of the challenge. In time the "board" a loose management structure could be expanded but it is a collaboration exercise, sometimes unpaid, to present thought leadership on how to best conceive and plan district heating.

The team recognise that there are lots of district heating examples across the world but few designed specifically to optimise the reward to the operator from best harnessing the reality that **heat pumps** (as the primary supplier of heat) have a highly variable output efficiency and due to the increasing price volatility, a highly variable cost input.
Adding a heat pump as an afterthought to any network can have highly sub optimal outcomes.

The three businesses recognising the unique skillset in this arena of the other partners, pledged in 2019 to pitch their collective skills at All-Energy2020 and began designing a fictional heat pump led scheme for the Glasgow metropolitan area. This work will be completed for presentation at All-Energy on an area bounded by the M8 in the west, High Street in the East, River Clyde in the South and the M8 in the North.

We will therefore build on this existing body of work and undertake a specific heat pump assessment for the district, with particular focus on harnessing heat from the River Clyde via water source heat pumps. Other sources of heat will also be considered, including waste heat and sewers. The value here is the majority of thinking has already been done, so the University and partners are will see the benefit of this considerable effort within the climate neutral Glasgow city study.

The output of this stage will be an overall Technical Note, supported by mapping and other visual representation of the proposed heat pump systems.

District Energy Networks
Atkins has a strong track record of assessing, designing and delivering significant scale district heating networks across Scotland. In Glasgow this includes major networks at Queens Quay (water heat pump scheme) and the University of Strathclyde campus scheme (working with Vital Energi). As such, we understand the challenges and opportunities to deliver genuinely sustainable low carbon networks in a city context.

We believe the overall district energy network review should include consideration of both heating and cooling, to ensure a holistic overall strategy with the potential to reduce the maximum quantity of

carbon. There will be a particular opportunity to integrate cooling distribution where large water scale heat pumps are being considered (see previous task).

Atkins and Star Renewable Energy will undertake an area wide district energy network assessment for the study area, in order to understand how this could be integrated as part of the overall whole system approach for the climate neutral district. We note the linkages to the 'Heat Pump' task above and propose the district energy network review is carried out in parallel, as one 'joined-up' exercise.

As part of this task we will liaise with a number of our trusted supply chain collaborators, including Vital Energi, who are the UK's leading district energy design, build, operate & maintain delivery organization. Vital will be engaged to provide specific technical advice and to undertake soft market testing in relation to proposed pipework infrastructure and ancillaries.

Specifically, we will:

- Review and map energy (heat & cooling) demands across the study area, to understand the potential for networks
- Assess potential energy generation and storage sites/ locations, including the River Clyde (water heat pumps), the Polmadie EfW station (heat off-take) and any other viable sources (e.g. local air source, sewerage or waste heat sources)
- Map major building off-takes (public and private), including identification of key anchor load buildings to support the network
- Consider key spine routing through the city centre area, such as the routing from the River and Polmadie to the city centre
- Review the potential to utilise existing or planned infrastructure to limit cost/ disruption to route networks e.g. existing tunnel systems underneath the city centre

The output from the stage will be a Technical Note, supported by GIS mapping of the feasible energy generation sources, network routing and key building connections.

Climate change risk assessment and vulnerability assessment and adaptation plan
We will undertake a review the existing studies and any relevant climate adaptation research by Sniffer, Scottish Government etc and complete a vulnerability assessment, which will consider the exposure and sensitivity of the proposal to climate change. We anticipate sustainable drainage and flood issues may be a greater concern than heatwaves or drought.

For "high" vulnerabilities, we'll complete a detailed risk assessment using a number of UKCP products; given the interest in 2 and 4 deg C we would probably use the derived projections[3].

We will then complete an adaptation assessment with reference to sustainability codes, building codes etc and identify suitable adaptation measures in partnership with sector experts. And finally, we'll assess the "Climate Action" credentials of the proposed development which will support the business case and financing.

[3]https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-fact-sheet-derived-projections.pdf as well as the UKCP probabilistic and UKCP Local data sets for heavy rainfall and extreme temperatures

The output of this stage will be a Technical Note summarising our findings, plus an overview of the proposed adaptation solutions and plan.