RUGGEDISED

Designing smart, resilient cities for all

Implementation report Glasgow

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Executive summary

Becoming a smart city is an integral part of the City of Glasgow's strategy to address climate change, air pollution, fuel poverty and an ageing infrastructure. The City has achieved CO2 reductions of 50% since 2006 and is committed to a net-zero emissions target by 2030, seeing the work of RUGGEDISED as helping to deliver these impressive results. The increased use of smart technologies and data will deliver better infrastructure and services and thus improve everyone's quality of life.

Since the City was awarded funding from the European Commission in 2016, the RUGGEDISED partners in Glasgow have worked to create a 'Smart Street' as the heart of a demonstrator area in the city centre through the implementation of ten RUGGEDISED solutions (G1-10). The ten smart city solutions were implemented with different levels of success as covered in this report. An overview of the implementation is also provided in the visualisation table.

The smart solutions specifically looked into:

- Increasing use of local renewable energy generated within the designated area;
- Increasing the use of electric vehicles to improve air quality and reduce CO2 emissions;
- Demonstrating that electric vehicle charging, intelligent street lighting and other controllable systems can be used as an additional tool in managing different loads in the power grid;
- Creating smart contracting models for local generators and consumers to better share heat and power;
- Providing better analysis and decision-making information to scale up smart solutions across the city.

Through the RUGGEDISED project, Glasgow had the opportunity to develop ground-breaking contractual models allowing companies, and other entities, to exchange surplus heat energy from one entity to another (G1). Extensive work, though not yet finalised, has also been undertaken to create an electric vehicle charging hub with a solar array and battery storage to both support the uptake of electric vehicles in Glasgow and potentially help alleviate peak loads in the energy grid (G2, G4 and G5). A solution connecting a brewery's heat and power production to batteries for electric vehicle charging (G3) was brought to a halt due to reaching the fault level limit in the electricity grid, and was thus not implemented.

Central for many of the solutions implemented in Glasgow is a network of intelligent street lights already deployed throughout the 'Smart Street' area (G6). These intelligent streetlights will be linked to a new Central Management System. Due to the pandemic, final installation and commissioning was not completed until late 2022. In addition to the possibility of charging electric vehicles, the lights installed will be connected to the other street lighting systems via the Command Management System. Unfortunately, the addition of the control node has not taken place prior to the end of the RUGGEDISED project, but is still foreseen.

Benefitting from a more connected city, the data shared through the intelligent street lights (amongst other smart solutions), is collected, analysed and visualised through a bespoke data-based decision platform, designed internally by Glasgow City Council, and used as a tool to shape decision-making processes for both the city and the wider public (G7). This platform is up and running.

A better-connected city will also allow the final three solutions in Glasgow to serve their purposes of reducing fuel poverty and providing the city with the tools needed for demand-side management of the power grid. Currently, demand-side management systems have been installed and are being tested in a domestic building (G9) and in connection to a building management system in a non-domestic building (G10).

Whilst a number of the smart solutions are still to be completed, with COVID especially having presented a significant challenge, there is considered to be value in the upscaling and or replication of these. The City of Glasgow is already in discussions about how to replicate these smart solutions elsewhere in the city and beyond. Once the smart solutions are fully complete, and demonstrable, this will assist in forward planning for further upscaling and replication.

Finally, on the organisational level, the City of Glasgow has taken important steps forward benefitting also from its work in RUGGEDISED. In the spring of 2022, the city was chosen as one of the 112 Cities in the EU Mission for climate neutral and smart cities, giving a stamp of approval to the Council's ambitions of reaching net zero emissions in 2030. On this journey RUGGEDISED partners in Glasgow have already played a key role, supporting the Sustainable Glasgow Initiative to connect local stakeholders and being an integral part of the Council's governance group as it takes on climate neutrality.

Progress summary visualisation table

Progress summary visualisation table	G1* Heat and Cold exchange	G2 Deployment battery storage technology	G3 Surplus storage in EV Charging hub	G4** Optimisation of the integration of near-site RES	G5 EV Charging hub in city centre car park	G6 Intelligent street lights with charging functionality	G7 Smart open data Decision Platform	G8 Demand-side management technology in street lighting	G9 Demand-side management in domestic properties	G10 Demand-side management non- domestic properties
Business model development Business model feasibility proven	✓ / 🏆	✓ / 🏆	N/A / ⛔	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆
Financial plan Finances approved by investors	✓ / 🏆	✓ / 🏆	N/A / ⛔	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆
Partners' Cooperation agreements cooperation agreements signed	✓ / N/A	✓ / 🏆	N/A / ⛔	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🕒
Project implementation plan development Project plan approved	✓ / 🏆	✓ / 🏆	N/A / ⛔	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆
Approval/permit procedures All permissions and notifications procured	✓ / 🏆	▬ / 🕒	N/A / ⛔	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆
Procurement process Key components procured	✓ / ⛔	✓ / 🏆	N/A / ⛔	✓ / 🏆	✓ / ✓	✓ / ✓	✓ / 🏆	✓ / 🏆	✓ / 🏆	✓ / 🏆
Project implementation Project commissioned	N/A / N/A	✓ / 🕒	N/A / ⛔	▬ / 🕒	✓ / 🏆	✓ / 🏆	✓ / 🏆	▬ / 🕒	✓ / 🏆	✓ / 🏆
Monitoring phase Monitoring completed	N/A / N/A	N/A / 🕒	N/A / ⛔	▬ / 🕒	✓ / 🏆	▬ / 🕒	N/A / N/A	▬ / 🕒	✓ / 🏆	▬ / 🕒
Upscaling phase Plans for upscaling	▬ / 🕒	▬ / 🕒	N/A / N/A	▬ / 🕒	▬ / 🕒	▬ / 🕒	▬ / 🕒	▬ / 🕒	✓ / 🏆	▬ / 🕒
Replication phase Replication planned	N/A / N/A	▬ / 🕒	N/A / N/A	▬ / 🕒	▬ / 🕒	▬ / 🕒	▬ / 🕒	▬ / 🕒	✓ / 🏆	▬ / 🕒

▬ In progress ✓ Done 🏆 Go decision 🕒 Pending decision **N/A** Not applicable ⛔ No-go Decision

* Parts of the solution was finished, but not the full solution. See solution for details.

** Physical implementation planned within weeks - or days - following the publication of this implementation report (October 2022)

Glasgow drivers for RUGGEDISED

Image: Glasgow City Council

The current period in which we live is characterised by rapid technological development, strong globalisation of (social and economic) activities, a need for protecting our living environment and ensuring social stability. In the European funded Smart City project - RUGGEDISED, three lighthouse cities of Rotterdam, Umea, and Glasgow, together with a number of partners from academic, business and consultancy backgrounds, are developing and testing the knowhow to explore and exploit opportunities that smart solutions offer in sustainable urban development.

The three overall aims of RUGGEDISED were:

1. Improving the quality of life of the citizens, by offering the citizens a clean, safe, attractive, inclusive and affordable living environment.

2. Reducing the environmental impacts of activities, amongst others by achieving a significant reduction of CO2 emissions, a major increase in the investment and usage of renewable energy sources and an increase in the deployment of electric vehicles.

3. Creating a stimulating environment for sustainable economic development, by generating more sustainable jobs, stimulating community involvement in smart solutions (as consumers and as producers) and boosting start-up and existing companies to exploit the opportunities of the green digital economy and Internet of Things.

Glasgow is committed to long-term plans for transformation and recognised the deployment of smart city solutions as a valuable means to create a sustainable, connected and healthy city. This was achieved through innovative smart city approaches; tackling environmental, infrastructural and socio-economic challenges and providing resilient solutions that integrated with Glasgow's strategic priorities.

As part of the RUGGEDISED project, Glasgow focused on creating a 'Smart Street District' that is situated along a section of George Street and Duke Street in the city centre, which has a mix of residential, community, academic, retail and industrial facilities. Drygate, situated along the 'Smart Street' is a densely populated area with a high level of its residents facing fuel poverty due to high fuel costs and electrically heated housing, even before the energy crisis of 2022. The investment plans in the 'Smart Street', and indeed the wider city approach, addresses the challenges Glasgow faces from: ageing infrastructure (brings high energy costs and frequent need for repair), fuel poverty and air pollution; by integrating planned regeneration and development with smart city capabilities.

The specific package of solutions worked on in the smart city demonstrator aimed to:

1. Maximise consumption within the district from local generation of heat and power from combined heat and power engines, and renewable energy generating assets;

2. Increase electric vehicle charging facilities and proliferation of electric vehicles in the district, significantly improving air quality and reducing transport related CO2 emissions;

3. Demonstrate that electric vehicle charging, intelligent street lighting and other such controllable loads (for example: buildings) can be incorporated into a demand-side management system, utilising the street lighting Central Management System and associated communications network to facilitate connection of these smart controllable 'devices' across the city that can support both generation fluctuations and provide localised electrical network support;

4. Create business models that enable local generators and consumers to contract with each other for the purchase & sale of heat & power; 5. Provide better analysis and decision making information to scale up smart solutions across the city. w

Implementation drivers to embark on RUGGEDISED

Glasgow has long been proud of its reputation as a city of transformation. One which blossomed due to the industrial revolution and the heavy industry that came with it, survived through its decline, and reshaped itself as a city of culture and innovation. In keeping with its ability to respond to the needs of an ever changing world, and to continue to cement its place as a leader amongst cities across Scotland, Great Britain, Europe, and beyond, Glasgow committed to becoming one of the most sustainable cities in Europe. These policies, along with the experiences from the earlier projects on innovation, helped shape the bid and desire for involvement in the Horizon 2020 RUGGEDISED project funded by the European Commission.

To support its vision of becoming one of the most sustainable cities in Europe, and to help Glasgow meet ambitious carbon reduction policies set out in Scottish, UK and EU legislation, as well as supporting other policy requirements on reducing fuel poverty and supporting economic growth, Glasgow Council, in partnership with the University of Strathclyde and the Scottish Government, established the Sustainable Glasgow initiative in 2010.

In 2010, the initiative produced a detailed report – the Sustainable Glasgow Report – on how the city could transform from a post-industrial city into a sustainable city. It also set a target for the city to reduce its CO2 emissions by 30% by 2020 compared with 2006, and set out a number of actions that would help the city achieve this ambition. The report from Sustainable Glasgow was a significant step forward in how Glasgow addressed issues related to CO2 emissions, fuel poverty, development planning, and economic growth. In addition to the Report, Sustainable Glasgow set up a board that included the city council, academia, major energy companies, the regional development agency and investment interests in the city.

The remit of the board was to develop and deliver projects that would support the city's ambition set out in the Sustainable Glasgow Report. The Sustainable Glasgow partnership now works to support the city's ambition of becoming Net-Zero Carbon by 2030. At the time of its writing, the Report utilised new methods of overlaying energy data with spatial data to assess the impact of city development in a more holistic way. Ultimately, the Report identified a number of broad technology approaches, such as combined heat and power (CHP) district heating, biomass, renewable energy systems, sustainable transport, phasing out high carbon fuels, energy management, etc., which could help the city achieve its 30% target. It also set out a process that could support the development of a realistic strategic framework that applied strong evidence to allow investment and carbon reduction project to be identified.

> *"The smart city can be defined as the integration of data and digital technologies into a strategic approach to sustainability, citizen well-being and economic development."*
>
> ***Scottish Government, 2014***

Sustainable Glasgow – Urban Innovation Platform

A key objective of RUGGEDISED was to support the delivery of an Urban Innovation Platform. Working with project partners in the Research Institute of Sweden, and following the declaration of a Climate and Ecological Emergency in 2019, Glasgow City Council looked at the Sustainable Glasgow partnership as a vehicle to help achieve the city's net zero carbon ambition by 2030.

Following a large launch event in February of 20, with attendees from various sectors across the city, including the arts sector, charities, SME's public sector and large businesses, the Sustainable Glasgow partnership was relaunched. This included a new focus on delivering projects to support real change in the city. The partnership was rebranded and in 2021, a new website was launched to showcase the work of the partnership in supporting the transition to net zero carbon. This can be explored here: https://sustainableglasgow.org.uk

Through the work of the partnership, the Sustainable Glasgow Business Charter was launched in June 2021, encouraging local businesses to sign up and pledge to improve their sustainability credentials and achieve net zero carbon. At the end of 2021 there were already 24 businesses signed up to the charter; including public agencies and private sector organisations. This includes NHS Greater Glasgow and Clyde as well as the Universities of Glasgow and Strathclyde. It also includes Glasgow Airport, Glasgow Chamber of Commerce, Babcock and Balfour Beatty.

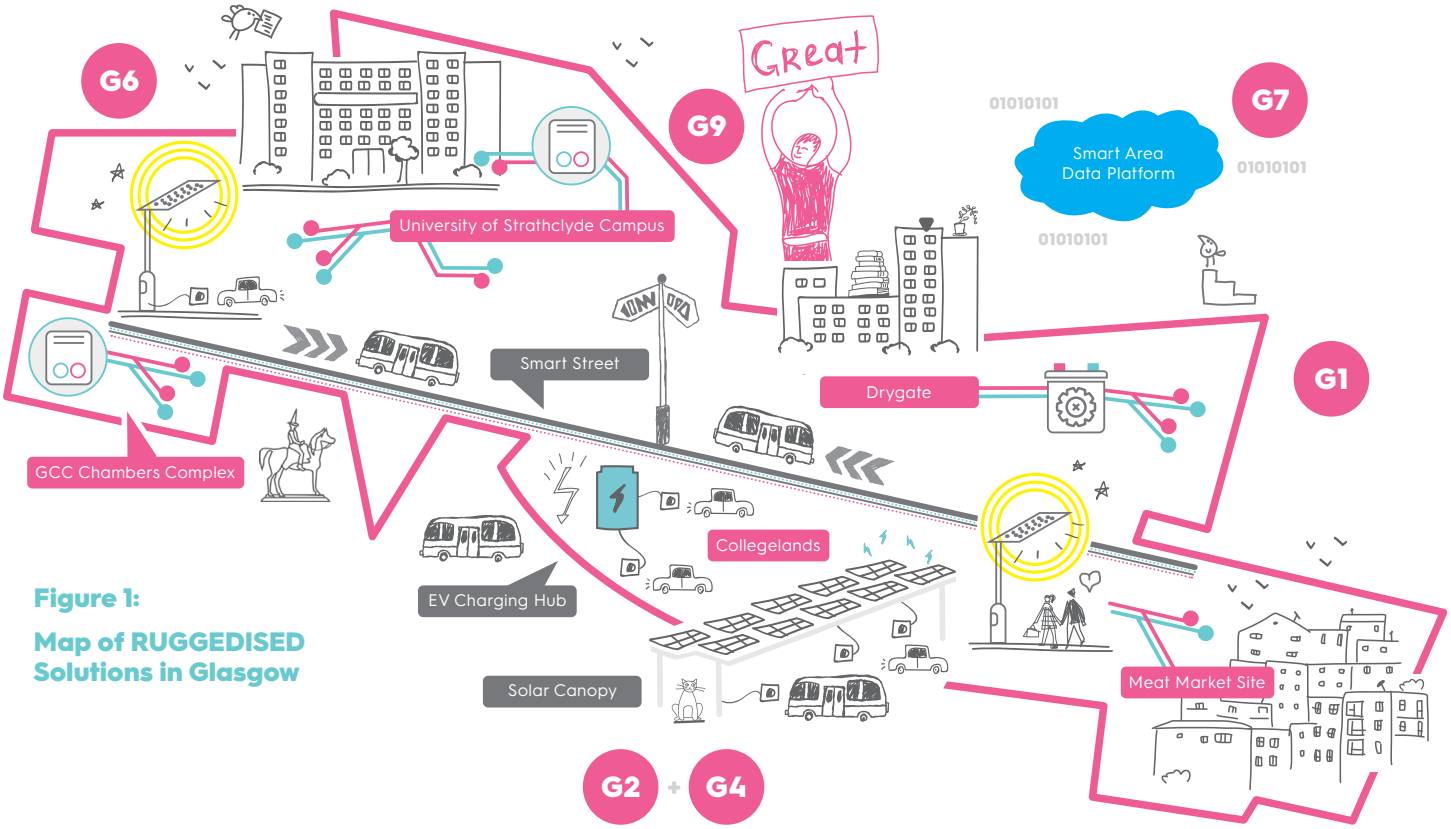


Figure 1:

Map of RUGGEDISED Solutions in Glasgow

Future Cities and innovation

Glasgow's innovative smart city work accelerated greatly from 2013 when the city successfully secured £24m of funding from Innovate UK to explore Glasgow's smart city potential to make the city more liveable by increasing public safety and sustainability through the use of technology. The project, known as the Future Cities project, concentrated on developing an open data platform, an operations centre, and four demonstrator projects to prove the smart cities concept that focused on intelligent street lighting, active travel, energy efficiency and integrated social transport.

Following on from the Future Cities work, the city developed its digital strategy. Glasgow' smart city vision is tied into its Digital Strategy for transformation of the city. Glasgow's Digital Strategy sets out the vision to create: A world class city with a thriving digital economy and community, where everyone can flourish and benefit from the best digital connectivity and skills, where technology is used to improve everyone's quality of life, drive businesses' innovation and service design an improve our city, its neighbourhoods and its success.

This vision is supported by two principle aims, each of which are supported by a set of goals that define the outcomes the city wishes to achieve. Firstly, to enable businesses across all sectors to realise the potential that digital provides, to stimulate innovation, and to establish Glasgow's tech sector as a top 20 Global Economy, and secondly, to ensure Glasgow becomes recognised as one of the most pioneering and innovative smart cities in the world.

European project involvement

In its journey before becoming part of the RUGGEDISED project in 2016, Glasgow established its involvement in European partnerships through a number of projects and initiatives. In 2012, Glasgow City Council joined the EU Covenant of Mayors and submitted the Sustainable Glasgow Report as its Sustainable Energy Action Plan (SEAP). Following on from this, Glasgow became one of the four cities involved in the European Commission's 'Strategies Towards Energy Performance in Urban Planning' (STEP-UP) project.

The aim of the STEP-UP project was to examine the SEAPs of the four cities of Glasgow, Gothenburg, Ghent, and Riga, and use them as the basis upon which a toolkit could be designed to help other cities across Europe create SEAPs that the Covenant of Mayors could review across a common basis. As a result of the STEP-UP programme, Glasgow enhanced the Sustainable Glasgow Report and replaced it with its Energy & Carbon Masterplan. This retained the 30% target and the 33 actions but added much more detail and analysis on how these would be achieved.

RUGGEDISED in Glasgow

The RUGGEDISED Project

RUGGEDISED is a smart city project funded under the European Union's Horizon 2020 research and innovation programme. It brings together three lighthouse cities: Rotterdam, Glasgow and Umeå and three follower cities: Brno, Gdansk and Parma to test, implement and accelerate the smart city model across Europe in partnership with businesses and research centres.

The implementation and embedding of RUGGEDISED into the city of Glasgow was based on the premise that RUGGEDISED would serve an innovation project supporting the wider strategy alongside, for example, with other projects and initiatives such as the Connecting Nature Project. The solutions were designed initially by the Glasgow consortium using previous experience and the solutions were then integrated into existing policies and frameworks such as the Local Heat and Energy Efficiency Strategy where RUGGEDISED is noted as a special project. Early on, a Governance group was then established to ensure that the project was embedded within all of Glasgow's policies and projects moving forward. The Climate, Energy and Resilience Group (CERS) was established to provide a reporting platform for the project, which brings all relevant senior officers together to monitor the progress of the project and facilitate its implementation. These senior officers then report through the Council's committee structures.

As of 2020, Glasgow had achieved and exceeded its target of 30% with a reduction of 50% in city-wide CO2 emissions.

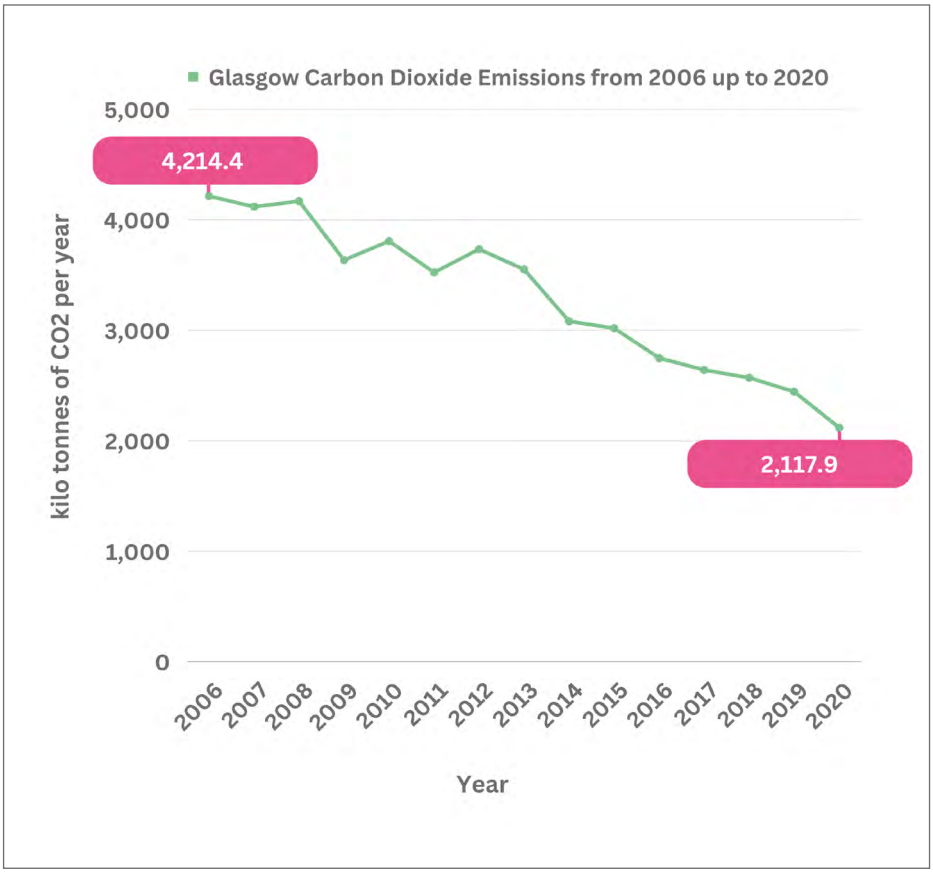


Figure 2: Glasgow CO2 Emissions 2006 – 2020

Source: City of Glasgow

Glasgow's Declaration of Climate Emergency

While Glasgow reached its target of reducing CO2 emissions, its approach to its smart city work – and sustainability in general – was transformed in 2019 when the city declared a state of climate and ecological emergency, setting out new targets to become net zero carbon by 2030. Whilst the city has always aimed to be greener and more sustainable, this declaration has allowed the city to address the key challenges and accelerate the pace of change in the city even further.

The delivery of the Glasgow's Climate Plan was a key milestone for the city to start progressing towards the target to achieve net zero carbon by 2030. With Smart City ambitions being a key action to facilitate the transition to achieving net zero carbon. RUGGEDISED is highlighted as a key case study within Glasgow's Climate Plan and features as a practical example of a smart city solution that will provide a significant amount of learning for the city moving forward. In particular the RUGGEDISED project will help Glasgow to reconsider and address issues such as fuel poverty, energy demand and electric vehicle infrastructure.

COVID-19 in Glasgow

In March 2020, the global COVID-19 pandemic hit Glasgow, halting normal life and bringing the city to a complete standstill. All routine work ceased and along with the rest of Scotland, Glaswegians were required to stay home, only being allowed out for essential purposes such as food shopping. The city's key workers, including the National Health Service, emergency services and other essential sectors such as energy providers and waste management continued to work throughout the pandemic, delivering vital roles to keep the city running and people protected.

The impact of Covid-19 was widely felt across Scotland and rest of the UK. The pandemic has also had a massive impact on the economy and business sector in the city, with a large number of organisations now supporting home and hybrid working. Glasgow City Council set up the Glasgow Economic Recovery Group (GERG) that aims to support a green recovery from the COVID-19 emergency. Working with partners in the Greater Glasgow and Clyde region, the city has helped to produce the Region's Economic Recovery Plan.

Due to changes in lifestyle, working patterns, use of cars, and public transport across the city, the data expected from the project was significantly different than initially anticipated, with, for example, far less people commuting into the city to work.

Carbon Literacy Training

Through RUGGEDISED, Glasgow City Council has now delivered Carbon Literacy Training, which is being rolled out across Glasgow. To date in Glasgow City Council this has included15 cohorts of training, incorporating 167 employees, including elected members, senior officers and a session of "train the trainer" to allow for further capacity building.

This has also allowed for capacity building in other partners with Police Scotland benefitting from the training prior to COP26, as well as COP26 volunteers undertaking this training ahead of the conference. This enabled the COP26 volunteers to develop their knowledge and understanding around climate issues but also to enable them to comprehensively understand the RUGGEDISED project and impart this knowledge to city visitors.

COP26 in Glasgow

Despite COVID-19, the City of Glasgow was the scene the 26th UN Climate Change Conference of the Parties (COP26) in 2021 – one year later than originally planned. The meeting of world leaders took place in Glasgow from the 31st October until the 12th November 2021, held at the Scottish Event's Campus in the city.

COP26 has proven to be a critical summit for global climate action, and demonstrated this through the Glasgow Pact with nations making strong commitments to achieving net zero and tackling the global climate and ecological emergency.

Glasgow was selected as the host city due to it being the only UK city to rank in the Global Destination Sustainability (SDG) Index, coming in 4th position in 2019 and recognised for it's commitment to sustainable business tourism.

In the lead up to the event Glasgow spent several months working with the United Nations and UK Government to ensure the city was ready for the conference. With COVID-19 still posing a threat, and challenges with travel restrictions remaining in place for many nations, there was a huge amount of uncertainty around the meeting, so we are delighted that the conference went ahead with successful results.

The Sustainable Glasgow partnership, delivered through RUGGEDISED as Glasgow's innovation platform featured at the COP26 conference, along with the RUGGEDISED project which was prominently featured in both the blue zone (delegates only) and green zone (general public) over the two weeks.

Image: Unsplash / Fredrika Carlsson

Description of smart solutions

Solution G1: Heat and cold exchange – Connection of buildings to district heating network

The city of Glasgow together with its partners developed the contractual models required to allow public sector buildings to sell heat from one to the other, and for private industry to sell heat to local housing, either directly or via an intermediary, such as an Energy Services Company (ESCo). Given that technological options are at hand, the challenge of implementing the smart solution was a matter of organisational innovation.

Concrete cases which were investigated included:

1. Use of surplus heat from Tennent Caledonian Brewery (TCB) by a local housing association owned by the Wheatley Group (WG).
2. Use of surplus heat from University of Strathclyde (UoS) DH network in Council headquarters.

General Description: The contractual model development for this smart solution looked at the potential for public and private sector partners to come to an agreement where they can trade heat between their organisations, so that both parties would feel the benefit of the agreement.

In the first case, Tennents Caledonian Brewery is a private sector organisation and the agreement looks at taking surplus heat generated from the brewing process, to the neighbouring highrise flats owned by the Wheatley Group, where the residents typically experience high levels of fuel poverty.

In the second case, the contractual models look at the transfer of heat between two public sector organisations by investigating transferring heat from the developing district heating network at the University of Strathclyde over to Glasgow City Council.

Expected Impact: The contractual models were developed to enable the organisational innovation required to allow future and developing networks to successfully connect to neighbouring customers or providers, and no longer serve only their own establishments.

The ability to efficiently use excess heat elsewhere would reduce overall costs, benefiting both suppliers and consumers, and also significantly reducing carbon emissions with a positive impact upon climate targets. The use of this type of contractual model as a Smart Solution will have a long lasting legacy post RUGGEDISED for the city of Glasgow, particularly now with the declaration of a climate emergency and the strengthened ambitions to meet net zero carbon by 2030, and the expected scaling up of such solutions as a result.

Despite efforts made by Glasgow City Council and Tennents Brewery, this project was unable to complete due to removal of national subsidy offer, thus negatively impacting the business case. Following this, The RUGGEDISED team worked in other areas of the city to develop alternative sources of heat delivery and is currently active in developing a Hydrogen powered district heating network in a major development in the city, as well as exploring heat extraction and distribution from deep geothermal wells (up to 6km in depth).

The contractual model continues to be a key enabler in bringing a range of stakeholders together to explore heat connections. In addition to the aforementioned, the RUGGEDISED team, particularly Glasgow City Council, the University of Strathclyde, and the Wheatley Group team has been working together on a Climate Neutral Innovation District (CNID) an area which encompasses the RUGGEDISED district, with one of the main proposals being to establish a river sourced heat pump powered district heating network, sourcing its heat from the River Clyde. Once again, the contractual model plays a key role in this work.

Final implementation stage: Smart Solution G1 was completed in August 2018. The development of this Smart Solution led to the creation of a "Contractual model for implementation". This has been recognised by all local stakeholders to be an accomplished piece of work that will enable more informed contract negotiations between generators and consumers of heat. The availability and use of this contractual model will support and facilitate easier establishment of heat connections in the future.

The contractual model is now readily available for both public and private sector actors to utilize as the basis of any relevant negotiations. The contractual model also includes a guidance note that provides highly valuable information on procurement regulations. It was considered highly useful to local stakeholders to include this guidance note stating how procurement regulations will affect potential consumers, thus giving confidence to any potential heat consumer that they are acting within their legal requirements.

The contractual model is available by submitting a request to info@RUGGEDISED.eu

An immediate implementation beyond the aimed achievements in RUGGEDISED, was unfortunately hindered due to issues outside the control of the actors involved in this Smart Solution activity. This has encountered challenges relating to personnel and resourcing within the organisations that were chosen to be part of the case studies. Thus the physical district heating connections between Tennents Brewery and the Drygate housing (Case study 1) and the University of Strathclyde and Glasgow City Council City Chambers (Case study 2) was not implemented.

The former (Case study 1) was impacted by a constrained power network which, in the area of the brewery, was close to its fault level limit. Due to this, they could not connect a CHP of the size required by the brewery. An alternative connection point was offered but, due to the distance away from the point of generation, it added £2M in additional costs to the project and rendered this uneconomical. Neither of these issues were foreseen in the design stages of RUGGEDISED and demonstrates some of the wider complex and unforeseen challenges that can occur during the implementation phase. The second case study, whilst in the planning phase, was hit with very high connection costs. This made the provision of heat from the University to the Chambers uneconomical. Despite a short geographical distance, the significant costs were largely due the very congested infrastructure underneath the roads in the city centre creating multiple routing issues for the pipe network.

The University of Strathclyde has also developed a district heating modelling tool with the capability to verify the effectiveness of the district heating connections for Glasgow City Council and the Wheatley Group. This tool has been added to the Energy Systems Performance building simulation platform. The tool can be accessed at --> www.esru.strath.ac.uk/Programs/ESP-r.htm for other cities wishing to explore the district heating potential in their own cities.

Innovation: Smart Solution G1 of the RUGGEDISED project has proven to be highly innovative. The city has never before had both public and private partners around a table to create template business models, which are designed to suit both sectors. The newly developed contract model has been viewed by other project owners as being cutting edge in terms of breaking down barriers between these sectors and providing a base from which other contracts and projects can start their negotiations. The model contract provides the framework for the private sector and public sector to base their negotiations.

G1 did not deliver signed contracts, instead, it delivered the framework and basis upon which contract negotiations for district heating will begin in Glasgow, and hopefully beyond. Thus putting the public sector in a much more informed position when negotiating heat contracts, and putting the private sector in a more informed position in relation to understanding what the public sector needs and wants in such a contract.

Connection to other smart solutions: This smart solution is linked to smart solution G3. It provides the basis of any district heating contract which is critical to the success of district heating projects. The successful installation of the CHP in G3 depends on a number of critical factors. One such critical factor is the contracted business of a sufficient number of heat customers to render this viable.

Connection to existing urban system and citizens / users: Through the development and use of these business models, Glasgow's heat network will become more connected. The contractual model enables Glasgow to move from 'heat islands' that stand in isolation serving only one development, to a more cohesive and joined up heat network, that will support low cost and low carbon heating. The contractual models have already been discussed for use in other developments in the 'Smart Street' with different partners outside of the project and they are proving to be of high value both in terms of innovation and replicability

Results: This solution is still being monitored. Future impacts will be assessed as more district heating networks are deployed in the city, and the transition to net zero progresses.

Upscaling plans: Glasgow has an aspiration to promote more district heating networks throughout the city. To date, district heating installed has failed to grow beyond its original boundary. Smart solution G1 provides a means by which discussions around new connections can be facilitated and brings potential customers and generators into a discussion from an informed position. During the life of the RUGGEDISED project, Glasgow City Council has been developing a Local Heat and Energy Efficiency Strategy (LHEES) in line with developing national guidance and methodologies. This strategy plans to designate opportunity zones in the city, based on areas that are conducive to exploring heat networks. Both G1 and D4.1 will play an important part in supporting the growth of district heating in these zones, by providing a clear framework to build on and instil confidence in stakeholders involved in the process. This work is still ongoing and this area is developing at great pace. With the requirement to ensure both domestic and non-domestic buildings will be net zero in the future, this piece of work will become even more integral in achieving Glasgow's net zero targets and likely to be commonplace in these negotiations.

In search for alternative applications of the contractual collaboration agreement, a new source of heat is also being explored for Tennents Brewery. This involves installing a large amount of boreholes in a piece of vacant land adjacent to the brewery and extracting and storing heat via heat pumps. The RUGGEDISED team in Glasgow has been involved in the development of this project and is working to have the model contract utilised in the contract negotiations should the project be successful. This is one of only many future developments that will benefit from the development of this smart solution, with continued roll out to take place across the city.

Replication assessment: The potential for other cities to use and replicate this solution is vast. This opportunity is particularly evident across Scotland and the rest of the UK, where district heating is still a relatively new concept and not yet an integral part of the heat network, unlike in other European cities where district heating is long established. The contracts have also been written in a manner that support the UK energy market, which may vary in other countries. We are getting more enquiries in regards to the contract model as further companies explore the opportunities and common sense that heat networks provide.
Lessons from this solution is being used in RUGGEDISED fellow City of Brno, for their plans for the Špitálka District and in Parma's plans for a district heating connection.

Solution G2: Deployment of a suitable battery storage technology in the project district

General Description: The Electrical Energy Storage (EES) proposed for implementation within the Duke Street car park was subject to consideration of the physical and electrical requirements of the location with respect to its proposed future role as an e-mobility hub. This would see the car park being used for increased charging for both private and taxi use, and also to support EV owners who do not have parking spaces due to the built up nature of the city. This represents the implementation part of a larger vision for Glasgow as a low, or zero, emission zone with the majority of vehicles being parked outside the central zone and pedestrian or e-vehicle transport being used within this area. Emerging energy markets, which are as yet only being considered, will drive such e-mobility hubs and the planned EES has been scaled to permit engagement in these markets. The implementation of the battery under RUGGEDISED will allow significant learning and a hierarchy of control which will allow for dynamic responses to CO2 reductions, fuel poverty alleviation and economic benefit which will all be governed by Glasgow City Council.

Due to the innovative combination of the technology, a business model for replication and upscaling of this solution, which considers future energy markets, is to be established post installation. There is the requirement to understand integration points and where best value can be gained.

Expected Impact: The EES was expected to deliver a number of impacts, technically, socially and financially. Without an EES the capacity of the current grid, to meet future electric charging needs during peak hours, could soon exceed grid limits. The EES permits charging to be managed by capacity, and timing to remain within the technical limits. In financial terms whilst the EES has a large up-front cost the saving in grid electricity costs (through the most effective use of locally generated PV power) and also trading in future energy markets should outweigh this over time. The EES also makes it possible to maximise the social benefit of reduced on street parking/charging as well as offering potential energy reserves for the fuel poor.

Final implementation stage: The EES is now on site at Duke Street car park. There had been an extensive procurement exercise, which was challenging due to the innovative requirements and technical specification of this solution. The appointment of a Glasgow based company to install both the EES and the solar canopy was made by October 2018. However, this company formally ceased trading in June 2019, leaving the future of this solution unknown and a time delay. The solution was put back out to the market, with new contractors awarded and due to commence work in 2020. Delays were encountered again however due to COVID-19. Whilst the battery has been delivered to the site it still has not been commissioned due to delays associated with the PV array on the roof. The array has been hampered by further complications in regards to structural design and high costs associated with Brexit. In March 2022 a choice was made that the design was redone to incorporate a structural ballast build and to not go ahead with the Canopy option. Once the array is deployed, the battery will be commissioned and the work done will be completed.

Innovation: This solution has incorporated innovation in many ways. The combination of scaling to suit the Duke Street car park type location, coupled with a generous PV array capacity and mixed use private and taxi company charging models is novel when viewed as an e-mobility hub. This concept of a destination for vehicles, both electric and fossil fuelled, where users then transition to a low carbon alternative transport system within a city is both exciting and innovative in itself. The innovation is still greater under RUGGEDISED however, since this is only a part of a larger city wide energy system combining domestic and non-domestic buildings along with city wide controllable street lighting. This controllable street lighting system considers the potential role of the system to meet local energy system needs and address fuel poverty. The system also presents an innovative approach to smart grid concepts, taking the car park beyond an electric vehicle charging hub to an integrated renewable electric vehicle hub connected to the grid and providing grid services. The Grid Interface Controller, developed by project partners Siemens, will allow the interaction between the grid and system to be dynamic.

Connection to existing urban system and citizens / users: The development of the electric vehicle charging hub through the use of solar PV and battery storage will provide the largest electric vehicle charging hub in the city that is powered through renewable energy. It will promote the uptake of privately owned electric vehicles and taxis throughout the city, therefore contributing to reductions in emissions and an overall improvement in air quality. The system also aims to further economic growth in the area by increasing use of the car park.

Connection to other smart solutions: This smart solution is linked to the creation of an electric vehicle-charging hub (G3) and local energy storage from Tennents brewery (solutions G3 and G4).

Results: This is pending connection when relevant monitoring will commence. Simulation data is currently being gathered by project partners University of Strathclyde. Project partners Siemens have also delivered a business model, including financial modelling, on the potential impacts of deploying battery storage as a potential technology to support EV charging.

Upscaling plans: Glasgow has six multi-story car parks owned by the wider council family, along with several other privately owned car parks. As such the replication potential for this solution is significant, with opportunities to provide grid balancing and support across the network as electric vehicle uptake increases over the coming years. Discussions are currently underway with a private company in the city to share learning through RUGGEDISED as they deploy their own EV charging hub. Work has also begun in regards to feasibility of creating hubs like these from RUGGEDISED, to be implemented at other areas in our city including our multi-storey carparks

Replication assessment: The potential for other cities to use and replicate this solution is vast. This opportunity is particularly evident across Scotland and the rest of the UK, where deployment of battery support to Solar PV is greatly being used or at least considered. There are many opportunities for Glasgow to demonstrate the multiple benefits of this innovate approach across our neighbouring municipalities through the Glasgow and Clyde Valley region, as well as sharing innovation through the Scottish Cities Alliance, which comprises a knowledge exchange network across seven Scottish cities.

The concept of this solution is also being investigated in the Fellow City of Brno.

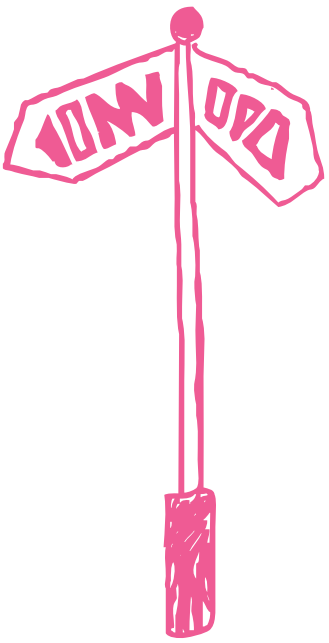
Solution G3: TCB CHP surplus power storage in EV Charging hub battery storage

General description: This solution is linked to G1,

The technological challenge is to have energy distributed from Tennents Caledonian Brewery (TCB) Combined Heat and Power installation (CHP) to battery storage for later use in city systems, such as EV charging. Business model required, both technically and operationally. The former requires the technical evaluation of how the energy flows to battery storage influence the generation priorities of TCB and the load profile of storage. TCB will establish a business model that facilitates power transfer from CHP to battery, and includes the resale of the energy from the battery. The regulatory challenge in relation to the potential distribution cost of using the local grid.

Final implementation status: As noted in G1, Tennents Caledonian Brewery were unable to install a new CHP due to the fault level limit on the grid. This complex challenge has ultimately directly impacted on delivery of this smart solution as it was initially intended. Because of this, the decision was made to further examine power transfer from the large scale battery to the smaller domestic battery that was being installed in the Drygate flats to act as a fuel poverty alleviation measure (G9). Due to space limitation and high connection costs, this larger battery was not installed.

Partners in Glasgow investigated the mechanisms for managing the potential power transfer in a way that could also reduce costs to the domestic residents. The UK network regulations make discount transfer possible but the cost would be socialised across all customers, this therefore was not considered a viable option. In tandem, work was undertaken to investigate the potential for a Power Purchase Agreement to be established with a not-for-profit energy company. Unfortunately, this company ceased trading in 2019 which prevented any progress on this matter. No alternative currently exists and as a result this smart solution will not be progressing at this stage. With the network hampering works, and the high costs of this at present, there may still be opportunity for these works in the future.



Solution G4: Optimisation of the integration of near-site RES

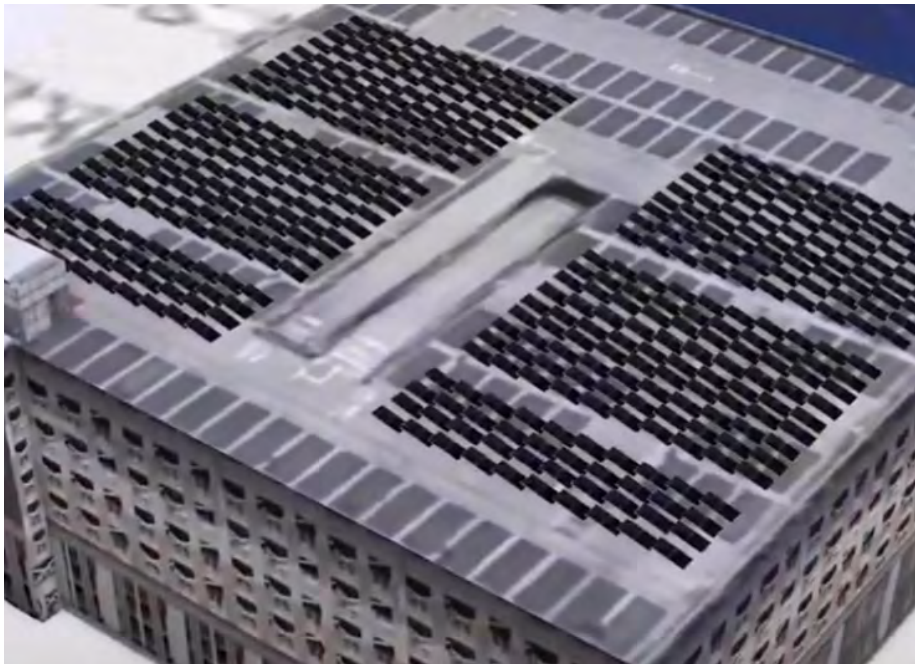
General Description:
This solution set out to install a 200kW solar canopy on the roof of a multi-story car park. The power generated by the PV array would be fed directly to either the building; to support its electrical load, and energy storage system, to allow for storage of the energy for use at a later time, or directly to the electric vehicle chargers (ensuring that electric vehicles in the city were as renewably powered as possible).

Expected Impact:
The expected impact of this solution was to maximise the utilization of locally generated renewable energy, with minimal export to the electrical grid, thus minimising the CO2 emissions associated with the operation of the car park and the charging of electric vehicles. The connection to the energy storage system would ensure that the maximum value should be gained for the power generated by offsetting the comparatively expensive costs of electricity imported from the grid.

Final implementation stage:
The installation of building-mounted wind turbines did not go ahead as modelling showed that the output would be minimal in comparison to a PV canopy. The appointment of a Glasgow based company to install both the Battery and the solar canopy was made by October 2018. However, this company formally ceased trading in June 2019. The solution was put back out to tender, with new contractors awarded and due to commence work in 2020. Delays were encountered again however due to COVID-19 pandemic. The impact of Brexit and the pandemic, resulted in escalating PV and steelwork costs. This resulted in a re-design of the PV system, to stay within budget. Further complications arose when additional structural remediation costs emerged due to the PV canopy design. This required a further re-design of the system, moving to a gravity weighted array.

The unfortunate cascade of circumstances above has resulted in significant delays in building and commissioning this system, beyond the one-year extension granted to the project. Currently the PV array remains to be installed but, it is anticipated that installation will happen before the end of 2022. Once the system is in place, project partner Siemens will return to install the Grid interface controller and provide data acquisition.

Figure 3: Screenshot from the modelling tool



In order to assess to a certain extend the potential impact of this solution, project partners from Strathclyde University are taking real time data from the usage of the carpark and producing simulated PV generation data which involved extensive modelling by project partners at the Energy Systems Research Unit (ESRU) based at the University. The outcome of the modelling work shaped the development and deployment of the renewables installed to be installed at Duke Street car park.

Modelling was undertaken for the Vertical Axis Wind Turbines (VAWT). This modelling found that whilst wind turbines have value in an urban environment, deploying them at Duke Street car park in parallel with a solar canopy, would lead to extensive shadowing of the canopy, and a reduction in overall power output. As such a decision was taken not to deploy the turbines.

The solar PV array was also extensively modelled by the ESRU. It was found that it would support the installation of electric vehicle charge units and building energy usage. However, the new design on the PV will have a direct impact on revenue generation from parking namely the loss of parking on the top floor. It was assessed and the usage of this floor is very minimal at this stage, so the decision was made to utilise the top floor for the PV array.

This early modelling report formed the basis of the procurement documents for delivery of the Solar PV canopy. Considerable work was undertaken, detailing the structural design and integration points, solar PV specifications, and connection to the energy storage solution.

There have been some unforeseen challenges in relation to this installation of smart solution G4. This has, however, led to learning for the future development and replication of this technology. It also demonstrates the dynamic nature of project implementation.

Please see --> appendix 1 for further information on the modelling works completed by project partners from the University of Strathclyde.

Innovation:
The innovative aspects of solution G4 relate to the nature of the installation and the integration with other assets within the Duke Street car park. In the future the roof of the car park functions as an area for parking cars, in the same way as the other floors. As a result of this, there would normally not be an opportunity to utilise this space for energy generation. However, by creating a bespoke canopy structure (as part of the existing steel structure) this would enable energy generation through solar PV without the loss of any parking spaces. This in turn would result in no loss of revenue generated through car parking costs. This has proved to be the most challenging aspect of the build and design and lessons learned will be valuable for the upscaling and replicating at similar multi-storey car park sites.

Although we wanted to install a canopy and in future builds to our other carparks, this will be a realistic option, the costs to complete would have made this build unattainable or a drastic reduction in size would have had to have been built which would not have supported the aims of 3 different solutions

Connection to other smart solutions:
G4 is linked to the deployment of battery storage (G2), the creation of an EV charging hub (G5) and the creation of a Data Based Decision Platform (G7) where the data from this technology will be analysed.

Connection to existing urban system and citizens / users:
The solar PV array, whilst providing renewable energy for use by electric vehicles. The availability of the EV chargers, being fed from the renewable energy directly generated by the PV or stored in the energy storage solution, is intended to support the uptake of electric taxis in the city, thus supporting the implementation of low to zero-emission transport for citizens.

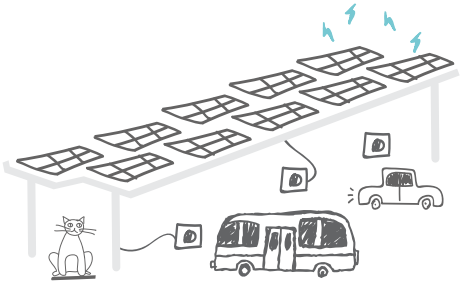
Results:
The implementation of this smart solution is still in progress. The University of Strathclyde continues to provide modelling support and simulating data generation to allow the expected impact to be compared to the actual impact once the full installation has been completed. These details will be available to all upon completion and data retrieval by contacting info@ruggedised.eu.

Upscaling plans:
With six other multi-story car parks owned by Glasgow City Council, and several other privately owned car parks, there is a significant replication potential for this type of technology. Sites of conventional open air ground car parks, also offer the potential to deploy this type of technology.

Replication assessment:
This solution is highly replicable across Glasgow, other UK cities and the rest of Europe. The key lessons and challenges experienced here will serve as valuable insight to others when looking to deploy this technology on other multi-storey car parks. This will enable foresight when considering the best options in relation to Renewable Energy Sources with consideration of potential conflicts between technologies. Key lessons are also replicable in terms of the structure of such renewable technology, the need for careful detailed designs and consideration of load bearing or other safety considerations dependant on the structure of the car park. Canopy PV arrays are starting to be deployed throughout Scotland. The potential to keep parking area for our citizens but also enjoy the benefits of renewable energy has been replicated, with private companies and train stations parking areas being deployed with solar PV canopies

In Brno, specific work is undertaken to exploit the options for integration of renewable energy systems in its Špitálka District.

Figure 4: The battery to support this solution has been procured and is ready for installation.



Solution G5: EV Charging hub in city centre car park

General Description: This smart solution looks at utilising a number of the car parking spaces in the multi-story car park to install electric vehicle (EV) charging points, increasing the number from four fast chargers and one rapid charger to 12 fast chargers and five rapids. The challenge is to develop the business case for concentrated deployment of EV chargers, alongside the connection of those chargers to renewable technologies and battery storage. The charge point installation at Duke Street car park is expected to support current EV drivers in the city as well as promoting other car users to switch to electric, facilitating Scotland's phase out of new petrol and diesel cars by 2032. The charging infrastructure is funded by Transport Scotland with the innovative connection to renewables and storage.

Expected Impact: The development of an EV charging hub should allow EV users to have a centralised, low carbon method of charging their vehicles. This smart solution also provides a test bed for establishing optimised power flows based on demand. The creation of city centre charging hub should enable taxi companies in the city to switch to using electric vehicles. If successful, this proof of concept was meant to influence the same type of infrastructure to be rolled out to other multi-story car parks.

Final implementation stage: Two 50kW charging units providing three different charging points each, have been installed in the car park with funding from project partners and Transport Scotland as part of the overall funding package for Glasgow City Council. These have the ability to charge four EV's at the same time. The chargers were initially anticipated to be installed at the front entrance of the car park, adjacent to the energy storage system installation. This location was chosen as it was expected to reduce costs by reducing cable length. Duke Street car park was designed with a channel on certain elevations for the installation of infrastructure, however due to the one-metre-deep earthing requirements of the chargers, the installations had to be repositioned towards the rear of the car park where a gravel channel exists to allow for installations such as these. The remainder of the chargers are due to be installed by the end of 2022, following an upgrade to the substation.

Figure 5: e-charger at Duke Street

Innovation: Whilst the chargers themselves are not a new technology, the way in which the system has been designed with the potential use of solar PV, battery storage, and a grid interface controller that manages demand and power flows is the innovative aspect of this solution.

Connection to other smart solutions: This smart solution is linked to the deployment of a grid scale battery storage solution (G2), the deployment of renewables that will provide power for the newly installed charge points (G4) and the data from this will be collected and analysed via the Data Based Decision Platform (G7).

Connection to existing urban system and citizens / users: The chargers have been in daily use and the first electric taxis have already been connecting to these chargers. Successful results from this smart solution will support the replication of this concept across other multi-story car parks in the city, facilitating a smooth transition to electric vehicles for car users in the city and supporting the city in the transition to net zero carbon.

Results: This solution is still underway as the creation of the EV charging hub is interwoven with the deployment of the battery storage and solar PV array at Duke Street car park. The EV charge points back end is managed externally, and work is underway to manage this data and integrate it with the Siemens grid interface controller, along with the rest of the system that is still being installed.

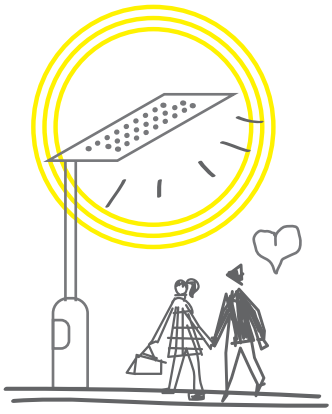
Once fully installed the results from this smart solution will be analysed, with some profile simulation expected due to a major shift in working patterns due to COVID-19. Pre-pandemic, the EV chargers were always used at capacity, and the car park was heavily utilised by commuters on a daily basis. As the city is currently only slowly returning to the office environment, with many companies now exploring hybrid working, the car park is experiencing a reduced number of users than previously.

Although not all the work has been completed on this deliverable, (the interconnection of the PV and battery), Glasgow has monitored the usage of the EV chargers showing steady use although lower than anticipated in 2016 due to the hybrid situation following Covid.

Upscaling plans: Once fully installed, this solution will be explored for upscaling opportunities at various sites across the city. Work is already underway to support a private company in creating their own EV charging hub in the city, and it is anticipated that GCC will also explore this option in the future. We are also looking at way to replicate this interaction of solutions at other areas in the city, possibly in our other multi storey carparks.

Replication assessment: This is a highly replicable solution both across Glasgow, Scotland and the UK. It is worthy of note that travel patterns have changed due to the COVID-19 pandemic. It remains to be seen if peoples need to commute to the city will remain less than before. Only when the city has made further progress in recovery from COVID-19, will the full advantages of this smart solution be evident.

Solution G6: Integrated EV charging functionality in Intelligent LED street lights



General Description: With approximately 70% of Glasgow households residing in flats, access to charging infrastructure can be challenging. This is both technical challenge and business case related. The intelligent street lighting with integrated electric vehicle (EV) charge points served as a test for the city where the street lights still remain on the toe of the pavement, therefore allowing charging infrastructure to be installed whilst minimising the impact on pedestrians and ensuring street furniture is kept to a minimum. The charging units installed were between 3.5 – 7kW as the expectation was that the use would be for businesses or domestic users with long duration parking requirements. The integration of EV charging into the street lighting column was funded by Transport Scotland and the street lighting has been funded through European Regional Development funding.

Expected Impact: It was expected that the installation of these integrated chargers would provide a different option for electric vehicle users, allowing them to access a less powerful charger, therefore placing less of a demand on the grid. There is often not the necessity to charge vehicles in a short amount of time, with residents living nearby to the integrated points having the option to connect for a longer period of time. This area has high residential usage so persons can be expected to park and use these charge points for longer periods of time which will complement the slow charging method.

Final implementation stage: The installation of the integrated EV charge points on Collin's Street was completed in 2021.

There were initial challenges due to the design of the integration. One of the main issues with this solution was the inclusion of the required cable sizes (16mm and 25mm) inside the lighting column, where there is not an abundance of free space. Furthermore, changes to the supply pillar earthing arrangement were required.

Due to the nature of the cabling requirements, the columns had to be replaced and were installed with the integrated chargers in 2021. The parking bays have yet to be designated and promotion of these charge points will take place in the near future.

Over 300 intelligent LED street lights have been installed within the project district.

Innovation: Having street lighting with integrated chargers is a new concept for the city. Until now, Glasgow did not have any 7kW chargers, or any integrated charge points. The data that obtained from these informs the city of their potential use and upscaling to other areas of the city. The integrated chargers will give the potential for more sophisticated control of charging through the intelligent street lighting network and central management system, as well as potential for future vehicle-to-grid possibilities in a demand management scenario.

Figure 6: integrated ev-charger

Connection to other smart solutions: This solution links in to the development of the EV charging hub (G5), the deployment of intelligent street lighting (G8).

Connection to existing urban system: The new street lights with integrated chargers are the first of their kind in the city. Engagement will be carried out with the local residents and current electric vehicle owners, users of the local amenities such as the neighbouring hospital, tourist attractions and institutions such as the University of Strathclyde to promote the use of these charge points over the remaining year of the project. Due to the nature of the district and demographic of residents closest to the chargers, the use has been very limited in the first instance.

Results: Monitoring of this solution will commence soon, along with promotion of the site as an EV charging destination, when previously this had not been available at this location. To date connection to the Command management system has not be done due to the installation of the control node not being installed. This has curtailed gathering information in regards to energy data usage of the chargers and lights.

Upscaling plans: Glasgow has a large number of tenemental and flatted properties, meaning that charging of electric vehicles at residential properties can be challenging. There is therefore a high upscaling potential for this smart solution, as using the street lighting as a charge point could enable residents to charge at home where it previously would have been impossible.

Demand for EV infrastructure in the city is at an all-time high. Glasgow City Council has a programme of installation of conventional EV chargers. Due to the nature of the residential buildings in the city, integrated EV chargers present a significant opportunity to help reach those people who cannot have their own charger. Further role out of these chargers is anticipated but is dependent on external funding awards. The Glasgow City Region started in 2022, an assessment of a regional approach to delivery of an EV charging network, designed to bring homogeny to the charging infrastructure across the city region. New network plans in Glasgow are now paused in anticipation of the results of the regional assessment. The learnings and data from the integrated chargers will be considered in this assessment.

As Glasgow continues on its journey to net zero, solutions such as these will be even more crucial in supporting the city in adapting to a new way of living. It will become much more evident that solutions like these need to be explored further in the Glasgow to support their citizens and the drive to polluting free vehicles in 2030.

Replication assessment: This solution is highly replicable, however be noted that this type of technology is only possible where the street lighting columns are at the toe of the pavement due to the potential trip hazard when connecting the electric vehicle charging cable.

In the city of Brno, a test is being planned for the rollout of electric vehicle chargers at public lighting columns.

Solution G7: Smart open data Decision Platform & central management system

General Description: The data based decision platform pulls together existing open data sets, along with the data generated from the project district to create a dashboard that allows users to analyse and present the data in a meaningful way without the need of data analysts. The idea behind the system is to allow individual users to customise their own dashboard, which allow them to view all of the chosen data sets at once in order to ensure the most efficient use of time, planning and resource across the city.

Expected Impact: The data generated by the project was meant to support to evaluate opportunities for new business models in relation to things such as energy storage and sharing, and EV charging for electric taxi's, as well as generating unforeseen business cases. The DBDP should also be able to cross reference datasets, including those from our project partners in Glasgow and across Europe, and create bespoke visualisations that will inform the creation of business models. The DBDP was to be an important tool to assist in achieving ambitions as a city to become net zero carbon by 2030. More specifically, it should help support the roll out and spatial planning of actions to support Glasgow's Climate Plan and the Green New Deal for Glasgow.

Current implementation stage: The development of the DBDP is now complete, with Deliverable 4.5 submitted in October 2019. This particular Smart Solution has attracted a lot of attention and has already generated a number of potential use cases that will be additional to the upscaled deployment of the solutions delivered in the project. The DBDP can, via API's, ingest data created by the project, as well as existing open datasets that will have the potential to better inform strategic and, potentially, operational decision making.

The full Data Based Decision Platform deliverable can be read under Deliverable 4.5 and the platform accessed by going to: --> https://databased.site

Innovation: A data sharing agreement has been negotiated between Scottish Power Energy Networks (SPEN) and Transport Scotland (TS), thus allowing the former to fully understand the use of EV charges by vehicle type and frequency, and the latter to know how the network is coping with the growing charging infrastructure. The data generated, and the outputs created from the combination of data, is already playing an important part in shaping partners approach to Electric Vehicle charging in the city and it informs Glasgow City Council's strategy for transforming vacant and derelict land sites into Electric Vehicle charging hubs.

The sharing of data between SPEN and TS is a major achievement and has unlocked a lot of potential improvements. The development of the DBDP continues to garner significant interest and looks to be one of the most significant deliverables from RUGGEDISED with regards to wider application and results generation.

There were found to be some tools that had functionality close to that required by the DBDP, but none were able to be deployed easily within the GCC corporate IT environment. Furthermore, to ensure the solution developed has a legacy within the council, the tool had to align with the existing GIS product suite and data environment. The platform was therefore built in house on existing Glasgow City Council infrastructure on the Microsoft

azure platform, meaning staff already had, and can be expected to maintain, the capacity to use the system. It also means that the system is bespoke and unique to Glasgow.

Connection to other smart solutions: This smart solution spans across all of the other data generating smart solutions. Data will be pulled from the other solutions via the wireless communications network (WISUN) installed on the intelligent street lights to be analysed using the data based decision platform. It will also be used to influence replication and upscaling of smart solutions by helping to visualise combinations of empirical data generated both by the project and by related external sources. The relaunch of Sustainable Glasgow will act as the city's innovation platform and will utilise the DBDP in designing solutions and policies to combat climate change. The database is now being upgraded to incorporate more in detail GiS mapping tools to enhance its capabilities, allowing more information and visual representation to further aid users. This is being developed by its original creators whom have now been able to return to the regular duties after redeployment to pandemic relief.

Connection to existing urban system and citizens / users: On completion of the platform, its use within Glasgow City Council, project partner organisations and also the general public have been looked into and a continuous upgrade is needed to make sure the platform and information remains current. The platform has been set up in a way that allows different users to have different levels of permission depending on the data sets and privacy issues. Further engagement will now be done with different stakeholders to ensure that the system meets their needs before further upscaling work and development takes place.

Results: Monitoring of this solution is still ongoing, with further engagement work required to fully utilise the system. Due to COVID-19, resources and priorities for GCC were focused elsewhere. The DBDP had concluded its work for RUGGEDISED Project. Delays in deployment of some of the smart solutions has also led to the DBDP not being utilised as fullest potential, and this will be fully realised when the installation of all of the hardware has been completed. The DBDP is also now going through an upgrade incorporating more in details mapping tools and extending its database capabilities that will allow it to be used by projects in the GCC and its partners.

Upscaling plans: This solution is now been looked at to be further enhanced by adding a wider range database and better mapping tools. Where relevant, additional datasets will be incorporated into this smart solution. The data based decision platform has been designed to be used city wide. Data from the deployed technology will be analysed using the DBDP, therefore supporting business models to deploy the technology elsewhere in the city. The DBDP therefore acts as a tool to enable upscaling of all of the other smart solutions.

Replication assessment: The platform itself can also be replicated to other cities, both across the UK and across Europe, with data sets from our partner cities already being used in the DBDP.

All RUGGEDISED Fellow Cities have also developed, or a planning too, urban data platforms.

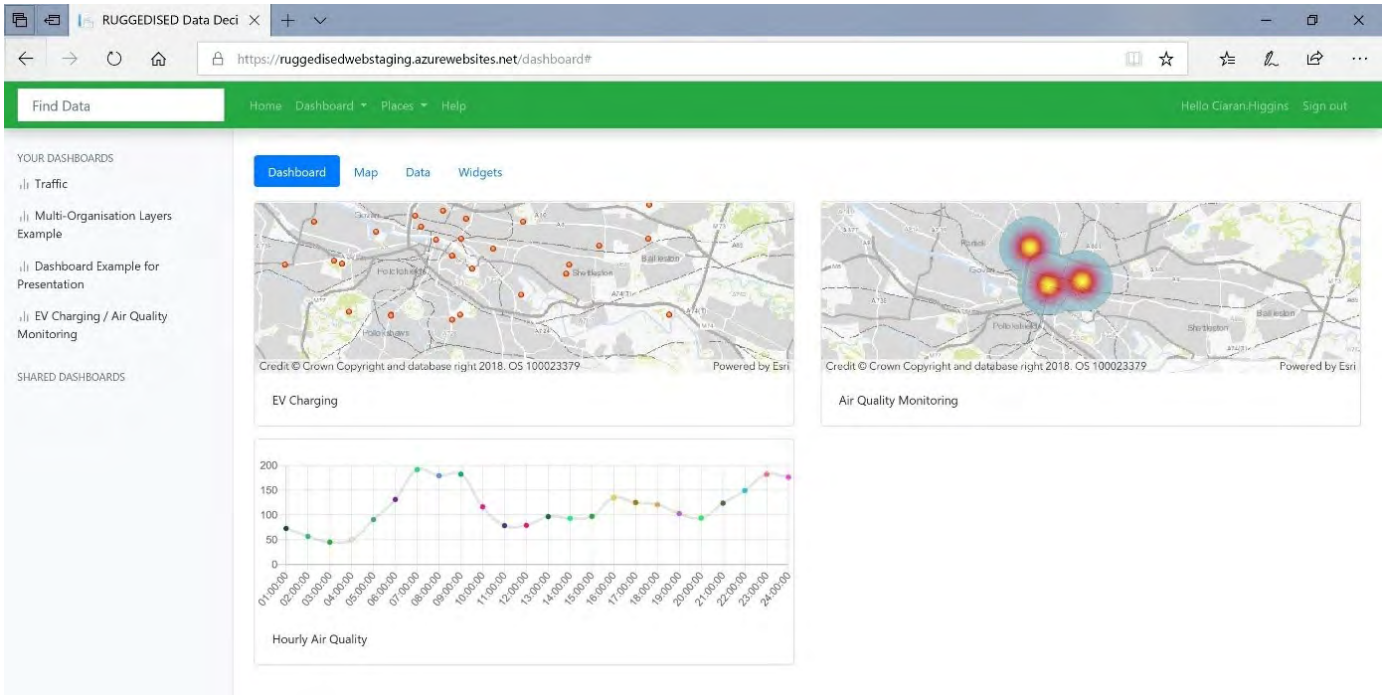


Figure 7. Demonstration of the Data Based Decision Platform

Solution G8: Implementation of demand-side management technology in street lighting

General Description: RUGGEDISED sought to understand how Demand Side Response (DSR) can be cost effectively delivered from new low energy street lighting, particularly that managed as a system. This depends upon simple, standardised communications connectivity.

Expected Impact: Street lighting is ubiquitous in most cities and with the wholesale switch to energy efficient LED luminaires in full swing a number of benefits can be quickly achieved. However, the lower energy requirements in LED luminaries also reduce the benefits of DSR since there is a smaller amount of available, spare, energy to work with, so the innovation in RUGGEDISED will be to investigate what level of DSR can be achieved using the simplest, most replicable and straightforward approach possible.

It was also anticipated that the overall carbon reduction from the installation of the intelligent street LED lighting would be around 60%.

Final implementation stage: The new intelligent street lighting is in place and Central Management System is being trialled. An IoT Edge Router has also been installed which allows the internal network to communicate with the wider internet for enabling IoT capabilities in the future. The node used for communications with the lights on the Smart Street was unfortunately not installed so control and monitoring had not been properly instigated. This will shortly be rectified and the node will be installed allowing completion of this deliverable. Once installed GCC will look further into the capabilities of this system

Innovation: With a 30% dimming functionality the street lights are now all controllable from a centralised location, meaning that the luminance, for example, can be increased in certain locations and decreased in others in response to an event, or alternatively reduced city wide to ensure that the power can be utilised where demand is greatest.

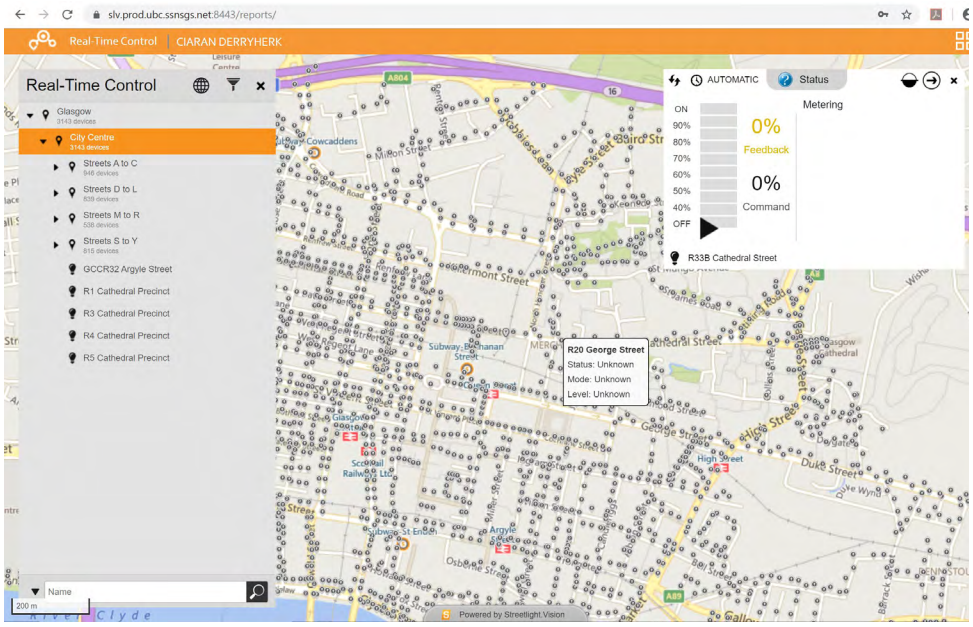


Figure 8. Demonstration of the central management system showing street lighting across Glasgow

Connection to other smart solutions: The intelligent street lighting serves as the communications network that allows for the transfer of data from the assets to the data based decision platform, and therefore serves as a mesh that pulls the 'smart street' together. The data that is transferred using the intelligent street lighting will be provided from G2, G4, G5, G6 and G7.

Connection to existing urban system and citizens / users: The system aims to make the city far more connected without the need for physical wiring, therefore reducing the disruption to the community and facilitating the transfer of data. The new intelligent street lights also aim to improve the liveability of the city by introducing LED lighting with a decreased luminance and therefore reduced light pollution.

Results: The monitoring of this solution will begin shortly with the added communication node to the innovation street.

Upscaling plans: This solution is already being rolled out across the whole of Glasgow.

Replication assessment: This smart solution has replicability at both a national and international level, as command and control as well as dimming capabilities for our street lighting would benefit any country utilising a system like this solution, with energy saving, lower carbon emissions and less strain on the electrical grid.

The cities of Parma and Brno are both making plans for the use of demand-side management technology in street lighting.

Solution G9: Implementation of demand-side management technology in domestic properties

General Description:
This was a new area that RUGGEDISED investigated and could have wide ranging impacts and learnings, domestic properties being occupied by individuals will need careful implementation if any interventions are not to either cause disturbance to these or simply be overridden through local control or usage patterns. The challenge was in developing a Central Management System in Glasgow to integrate domestic properties into a 'smart grid', thus allowing demand-side management events to be triggered that benefit both the grid and the residents. In essence meaning the domestic properties become capable of soaking up energy when the renewable production is high, or share energy, when renewable production is insufficient. Deploying technology is not enough, and it is essential to ensure that a full understanding of the potential of demand-side management was achieved in a domestic scenario. This solution included exploring the potential to activate cheaper tariffs for residents when renewable generation exceeds demand. The impact of local storage was also analysed.
RUGGEDISED solutions aim to provide individual tenants increased control of their own energy usage through domestic energy-management systems, focused on heating especially.

Expected impact:
It was hoped that the deployment of these solutions will not only support with demand side management, and thus an increase the overall use of renewables in the grid, but also facilitate a study in to the alleviation of fuel poverty through the deployment of domestic battery storage. Ideally, the solution should allow residents to save energy, cut costs and increase their quality of life.

Current implementation stage:
The 'Connected Response' technology to manage energy-use has been installed in +100 flats in Drygate and is being used by residents. There have been many unforeseen issues with the domestic battery procurement due to the size, location of the storage room to house the battery and fire suppression systems. The first company procured could not deliver the system with the fire safety guarantee, therefore the contract was terminated and another company procured. The location of this battery has been changed due to issues with asbestos, electricals, and fire detection and will now be housed within the concierge office serving the Drygate flats. The installed system was in place by October 2019 and has a 45kWh capacity and 9.9kW charge/ discharge rate. On completion of this, the system has been connected to the Grid Interface Controller provided by Siemens. Please see appendix 3 for Heriot Watt's updated report on this smart solution.

Innovation:
This was the first trial of this system in Glasgow, where there are large numbers of properties using outdated electric storage heater systems, due to a legacy of nuclear energy. The aim of this was to alleviate fuel poverty in a small number of properties, with a view to up-scaling this solution if it proves to be successful.

Connection to other smart solutions:
This solution is connected to the Siemens Grid Interface Controller deployed to control the power flows of the renewables and battery storage at Duke Street and is therefore also linked to G2 and G4.

Connection to existing urban system and citizens / users:
Where the effects of the other smart solutions will be felt across the city and to users of the district, this smart solution is of most importance to the residents living with fuel poverty in the district. This solution is connected to the wider RUGGEDISED ambition of creating a micro-grid and this element allows the local citizens to feel the benefit of such a system. If installation of the renewables and battery storage at Duke Street car park go ahead, this domestic system will also have the potential to connect, allowing further DSM scenarios to be explored.


Image: Wheatley Group

"With the old overnight storage heating tariff, I used to put my washing on during the night because it was cheaper. Sometimes I'd put a stew on to cook slowly too."

"Now I have more control over when I use my electricity. I have heating and hot water when I want it"

Resident in the Drygate flat following installation of smart meters

Results:
The platform that manages the battery operated by Heriot Watt University has been producing data since 2021. Monitoring of this solution is ongoing with information and test scenarios been run by the Siemens Team through there DEOP. These results have been presented in the deliverable report for G9.

For individual residents and the Wheatley Group, the results has been positive:

- The solution has lowered the cost for residents vis-à-vis the traditional system.
- Surveys prove higher comfort for residents.
- The technology has been shown to reduce energy use by up to 30%
- Prior to 2022 (and the rise in electricity prices) the technology cut bills by up to £300 per year.

Upscaling plans:
The part of the solution targeted tenants directly is being upscaled to at least 10,500 households across Glasgow and 2 other local authority areas in Scotland (Edinburgh and Dumfries) through ambitious investments from the Wheatley Group and partners, there is a £10.5 million programme planned up to March 2024.
The central demand-side management hub has potential to be improved upon and expanded with Glasgow now looking to retrofit all of its domestic and non-domestic properties across the whole of the city to a net zero standard.

Replication assessment:
Due to the UK having several high rise apartment blocks in the city, and also properties with old inefficient electric storage heaters, there is high replication potential for this smart solution. If the results prove this technology to be successful, a business case will be looked at for assisting other housing associations in deploying this technology.

Image: Unsplash / Giorgio Trovato

Solution G10: Implementation of demand-side management technology in non-domestic properties

General Description:
This solution examines how non-domestic buildings can be used in a demand-side management context to be part of a 'smart grid'. From a technical perspective, the communications will be via the Intelligent Street Lights mesh radio network using an IoT Edge Router device. This will communicate with the existing Building Management System (BMS) controller within each building and relay signals to/from the Demand Side Management controller (DSMc) when seeking to perform a demand-side instruction. The BMS will always be in control of the connected building loads and when an instruction is received from the DSMc, local environmental setups will be assessed before any loads are curtailed. If the BMS is able to shed load, a positive response will be provided back to the DSMs. If it is not possible to shed load, a negative response will be sent.
Non-Domestic buildings are a major contributor to CO2 emissions in cities and understanding how they can work harmoniously with other resources to deliver DSR services is important learning for Glasgow and cities in general.

Expected impact:
Earlier projects have demonstrated the capability of non- domestic buildings to deliver worthwhile demand-side response benefits, however communications issues and complexity have made the up-front costs quite high and reliability lower than expected. RUGGEDISED wasl seeking to increase the reliability and ease of communications connections through the use of the mesh radio system allied with the ISL rollout, this should provide important learning as to how a larger fleet of buildings across a city can be implemented cost effectively going forward.

Final implementation stage:
The RUGGEDISED partner Siemens has the IoT Edge Routers and are working with the ISL network providers - Itron - to configure them for communication across the network. Site visits were planned to confirm that the IoT Edge Router can communicate with the BMS (via the 'eMic' device installed as part of a previous project), and as the configuration has not been changed it was expected to work without any modifications required. Site visits were delayed significantly due to COVID-19, with no travel allowed between England and Scotland and the full closure of the Glasgow City Council buildings for a significant period of time. Siemens were eventually able to access the GCC site in 2021 to access the previously installed kit and take to their factory for configuration. After long problems with the communications protocols a solution was found and final connections started in August 2022. Connection was established with intermittent signal strength disrupting communications further. A signal booster, added in late October 2022 will boost all communications and allow a full DSM protocol to be established. Testing is still going on and real time data acquisition has started. To allow full capabilities with the DEOP to be explored testing scenarios are being sent for which is reported in our deliverable report.

Innovation:
This project builds on a previous project, so the implementation of demand-side management is not new. The number of different loads under the control of a single demand-side management controller is also novel as all previous control has been via a dedicated system that only deal with one load type. Having different loads, which consume energy in different ways increases the possibility for demand-side management at different times of the day and under differing environmental conditions.

Connection to other smart solutions:
There is a potential to create a dashboard in the Data Based Decision Platform(G7) that can indicate if a demand-side event is occurring, or the result of such events. It should be noted, however, that this has not been implemented.

Results:
This solution is almost complete with the final communications problems being finalised and DSM signals being sent, it will be just a matter of data retrieval over the coming year.

Upscaling plans:
As noted previously, the need for non-domestic buildings to achieve net zero is now more pressing than ever due to the target for Glasgow to meet net zero carbon by 2030. Solutions such as this will therefore need to be fully explored as a way to contribute to achieving this target and once the full results have been analysed, a detailed upscaling plan will be explored. The communication stability, capability to add more buildings to expand the network and to add more systems which can be included into DSM events will be the focus for our upscaling plans

Replication assessment:
There is high replication potential for this smart solution with the potential for further non-domestic buildings to be added on to the system over time.

Conclusions

For Glasgow, the period of RUGGEDISED implementation from November 2016 until October 2022 has been one of dramatic change, both for the better and – at times – for worse.

Today, Glasgow is not only more sustainable thanks to ambitious leadership cutting CO2 emissions in half compared to 2006 levels, it is also becoming known for its sustainable leadership around the world following COP26 in 2021. This leadership has also been recognised with Glasgow being one of only two UK Cities chosen for the EU Mission on climate neutral and smart cities.

However, these results do not tell the full story of a period that dealt blows through first Brexit and then the COVID-19 pandemic followed by the sharp rise in energy prices in 2022. In fact, while Glasgow had already delivered the majority of its CO2 reductions pre-Covid, the introductions of lockdowns did (seemingly) contribute to the final reductions in 2020.

It was within this period that the RUGGEDISED partners in Glasgow had to navigate, implement and support the wider efforts to transition towards a more sustainable Glasgow. The project partners did so successfully by developing ground-breaking contractual models allowing companies and other entities to exchange surplus heat energy, the implementation of electric vehicle chargers, a data platform, intelligent streetlights, and pushing forward important work on energy demand response.

Figure 9: Gavin Slater, Head of Sustainability at Glasgow City Council presented the lessons from RUGGEDISED at its final conference. Photo: Li Yuan Photography

In Glasgow, important lessons have also been drawn on solutions that will not be implemented or have had to be postponed until after the end of the RUGGEDISED project. Complications, especially in regards to procurement processes or technology implementation gaps, have set the baseline for future action in Glasgow, with emphasis on setting up internal efficiency processes, as well to work closely with partners to design effective and resilient solutions. For example, Glasgow is still waiting to deploy a solar array and battery which will support the uptake of electric vehicles further.

A solution that has been implemented, and in fact is already being upscaled, is the Wheatley Group's work on domestic demand-side response. The installation of small smart metres in flats not only lowered energy use, it also provided residents increased control and has proven to be a small part of the puzzle in fighting the current energy crisis in Glasgow, following the rising prices of energy in 2022. The solution is planned to be upscaled to 10.500 households.

Finally, there are the less tangible though just as important results of RUGGEDISED: the RUGGEDISED partners in Glasgow have used the knowledge stemming from the project to support carbon literacy training, the re-launch of Sustainable Glasgow connecting stakeholders in Glasgow and the strategic steering of the City Council's decarbonisation programme.

Moving forward, the solutions in Glasgow will be monitored and the learnings will continue to support its path towards becoming climate-neutral in 2030.

Glasgow after RUGGEDISED

Following Glasgow joining the EU Mission on climate neutral and smart cities, and consistent with its role as host city for COP26, the city now needs to look at its existing commitment to be net-zero carbon by 2030 and consider how it can set a target to be climate neutral by 2030. This target broadens the scope of our climate target but maintains the impetus put in place by our climate plan and net-zero carbon target.

Following on from RUGGEDISED, and as part of our ongoing climate work, the city is looking to invest multiple millions into growing our renewable energy generation and linking it to battery storage, learning important lessons from the work undertaken in RUGGEDISED. We will also be putting significant effort into growing district heating networks in the city, developing heat network zones in the city that will support and enable the development of renewable heat delivery through district heating to public, private and domestic sectors, utilising the work in RUGGEDISED building our district heating contracts.

Financing has been a key challenge during the smart city solutions development in Glasgow. In order to better advance on a sustainable implementation model, the city has worked to find other sources of finance

such as the Innovative UK Fund, or EU regional development funds to secure the long-term implantation of the measures. In the future, the city will also be further developing a new approach to financing the transition to a net-zero carbon and climate neutral city and is developing a 'Green New Deal' for Glasgow. This will look at innovative ways to bring in funding to the city to support the predicted £40B required for the transition. This finance will seek to blend public and private funding to help finance the transition. In addition to financing the transition, the city has established a Just Transition Commission to ensure that the transition is managed in a way that makes sure that no sector of society is further disenfranchised by the transition.

The Sustainable Glasgow network is, as the city innovation platform, crucial to the delivery of the transition and is central to a very important development and evolution of the very location of the RUGGEDISED Smart Street. The Smart Street is located in an innovation district in the city centre, one of a number of innovation districts in the city, and based on the work of RUGGEDISED, the development of the climate plan, the pressure of the climate and ecological emergency, and the newly published Adaptation Plan for the city, has now developed a plan to become the city's first Climate Neutral Innovation District (CNID). This CNID has completed its phase 1 feasibility study and includes the installation of an extensive and innovative district heating network, utilising the River Clyde, which bisects the city running through the very heart of the city and way the basis of the shipping industry in the city that allowed Glasgow to become a global port, before the demise of the industry and the last transition the city went through. The CNID also includes reduced vehicular access, enhanced EV charging infrastructure, again benefitting from the work of RUGGEDISED through its street-lighting integrated charging, and green and blue measures to enhance adaptation to the climate impacts of increased precipitation and the urban heat island effect.

The city is now also committed to developing a digital twin, further building on the data-based decision platform developed in the project and learning much from our colleagues in Rotterdam.

Finally. The city has established a new Climate and Sustainability Board and Programme Management Office to ensure the appropriate governance and expertise to deliver their climate aspirations and to provide the necessary support in the delivery of the actions required to achieve the goals.

In short, RUGGEDISED has been a catalyst to much of the innovative thinking and technology deployment, as well as to the management and governance associated with their delivery, and its legacy will be felt for years to come on the city journey to our 2030 target of being net-zero carbon and to becoming a climate neutral city.

Further readings on Glasgow's work and solutions

To find all reports from Glasgow's work in RUGGEDISED, please visit the RUGGEDISED Website on https://ruggedised.eu/cities/glasgow.

Disclaimer

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You can find the appendices to this report online at: www.ruggedised.eu/fileadmin/user_upload/Results/Appendices__Implementation_Report_Glasgow.pdf

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About the project
RUGGEDISED was a smart city project funded under the European Union's Horizon 2020 research and innovation programme. It brought together Rotterdam, Glasgow, Umeå, Brno, Gdansk and Parma to test, implement and accelerate the smart city model across Europe. Working with businesses and research centres these six cities demonstrated how to combine ICT, e-mobility and energy solutions to design smart, resilient cities for all.

About the publication
This is the final version in a series of three implementation reports from the European Smart Cities and Communities Lighthouse City of Glasgow. It details the work Glasgow has done through RUGGEDISED to become an even smarter and more sustainable city.

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RUGGEDISED
Designing smart, resilient cities for all

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