RUGGEDISED

Designing smart, resilient cities for all

Vol. 2

Implementation report Glasgow

Table of contents

1. Progress summary visualization table

Progress summary visualization table	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Business model development	✓	✓	N/A	▬	▬	▬	✓	✓	▬	▬
Business model feasibility proven	🏆	✓	⛔	🕒	🕒	🕒	🕒	🕒	🕒	🕒
Project development to prove viability and impact	▬	✓	N/A	▬	▬	▬	▬	✓	▬	▬
Project investment ready or bankable	N/A	🕒	⛔	🕒	🕒	🕒	N/A		N/A	N/A
Partners' Cooperation agreements	✓	N/A	N/A	N/A	N/A	N/A	✓	✓	✓	✓
Cooperation agreements signed	N/A	N/A	⛔	N/A	N/A	N/A	🏆	🏆	🏆	🏆
Project implementation plan development	▬	▬	N/A	✓	▬	✓	✓	✓	✓	✓
Project plan approved	N/A	🏆	⛔	✓	🕒	🏆	🏆	🏆	🏆	🏆
Approval/permit procedures	N/A	▬	N/A	✓	▬	✓	✓	✓	✓	✓
All permissions and notifications procured	N/A	🏆	⛔	🏆	🕒	🏆	🏆	🏆	🏆	🏆
Procurement process	N/A	🏆	⛔	🏆	▬	✓	✓	✓	✓	✓
Key components procured	N/A	🏆	⛔	🏆	🕒	🏆	🏆	🏆	🏆	🏆
Project implementation	N/A	✓	N/A	▬	▬	✓	✓	✓	✓	✓
Project commissioned	N/A	▬	⛔	🕒	🕒	🏆	🏆	🏆	🏆	🏆
Monitoring phase	N/A	▬	N/A	▬	▬	▬	N/A	▬	▬	▬
Monitoring completed	N/A	🕒	⛔	🕒	🕒	🕒	🕒	🕒	🕒	🕒
Upscaling phase	N/A	🕒	N/A	🕒	🕒	🕒	🕒	🕒	🕒	🕒
Plans for upscaling	N/A	🕒	N/A	🕒	🕒	🕒	🕒	🕒	🕒	🕒
Replication phase	N/A	🕒	N/A	🕒	🕒	🕒	🕒	🕒	🕒	🕒
Replication planned	N/A	🕒	N/A	🕒	🕒	🕒	🕒	🕒	🕒	🕒

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

2. Executive summary

Becoming a smart city is an integral part of the City of Glasgow's strategy to address climate change, air quality, fuel poverty and an ageing infrastructure. The City has achieved CO_2 reductions of 41% since 2006 and is committed to a net-zero emissions target by 2030, seeing the work of RUGGEDISED as helping to deliver on its ambitions. 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 centre of a demonstrator area in the city centre through the implementation of ten RUGGEDISED solutions (G1-10). The ten smart city solutions are currently in different phases of implementation, an overview of which is provided in the visualisation table.

The smart solutions specifically look into:

- MIncreasing use of local energy generated within the district;
- Increasing the use of electric vehicles to improve air quality and reduce CO_2 emissions;
- Demonstrating that electric vehicle charging, intelligent street lighting and other controllable systems can be used in 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;
- Provide better analysis and decision making information to scale up smart solutions across the city.

Through the RUGGEDISED project, Glasgow has had the opportunity to develop ground-breaking contractual models to allow companies and other entities to exchange surplus heat energy from one entity to the other (G1). Extensive work, though not yet finalised, has also been undertaken to create an electric vehicle charging hub with a solar canopy 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) has been brought to a halt due to reaching the fault level limit in the electricity grid, and will not continue at this time.

Central to 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 are linked to a new Central Management System, and in 2020 the installation of electric vehicle charging functionality, integrated into street lights, commenced. In addition to the possibility of charging electric vehicles, the lights installed already connect the city with other smart solutions deployed by RUGGEDISED through a wireless communications network.

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 provide the city with the tools needed for demand-side management in the power grid. Currently, demand-side management systems have been installed and are being tested in the intelligent street lights (G8), in a domestic building (G9) and in the connection to a building management system in a non-domestic building (G10).

Whilst a number of the smart solutions are still to be complete, with COVID especially having 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.

3. Glasgow and 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 know-how to explore and exploit opportunities that smart solutions offer in sustainable urban development.

The three overall aims of RUGGEDISED are:

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 CO_2 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 recognises the deployment of smart city solutions as a valuable means to create a sustainable, connected and healthy city. This is achieved through innovative smart city approaches; tackling environmental, infrastructural and socio-economic challenges and providing resilient solutions that integrate with Glasgow's strategic priorities.

As part of the RUGGEDISED project, Glasgow focuses 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. 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 package of solutions proposed in the smart city demonstrator aims to:

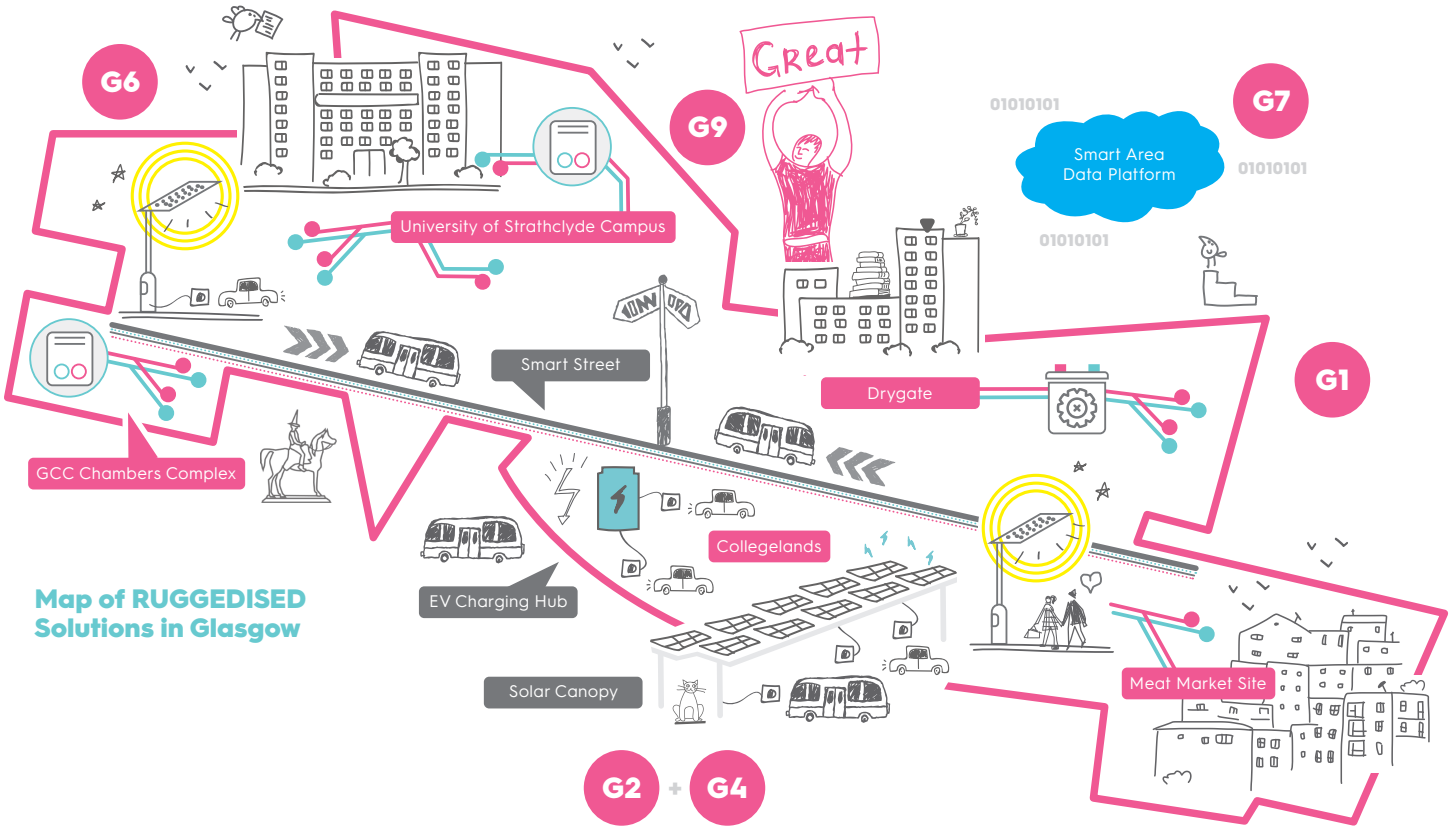
1. Maximise consumption within the district from local generation of heat and power from combined heat and power engines, and renewable energy generating assets;

2. Increase electric vehicle charging facilities and proliferation of electric vehicles in the district, significantly improving air quality and reducing transport related CO_2 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.



Map of RUGGEDISED Solutions in Glasgow

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.

Sustainable Glasgow initiative

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 CO_2 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 CO_2 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.

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.

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 projects and initiatives. In 2012, Glasgow City Council joined the 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.

"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

Image: Unsplash / Phil Reid

4. RUGGEDISED in Glasgow

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, 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 2019, Glasgow had achieved and exceeded its target of 30% with a reduction of 41% in city-wide CO_2 emissions.

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.

Glasgow carbon dioxide emissions from 2006 up to 2020

Figure 1. Glasgow CO_2 Emissions 2006 – 2020
Source: Glasgow City Council) Glasgow City Council Energy & Carbon Update 2018
www.glasgow.gov.uk/councillorsandcommittees/viewDoc.asp?c=P62AFQDN2U2UDNUTDN

Glasgow carbon dioxide emissions from 2006 up to 2019

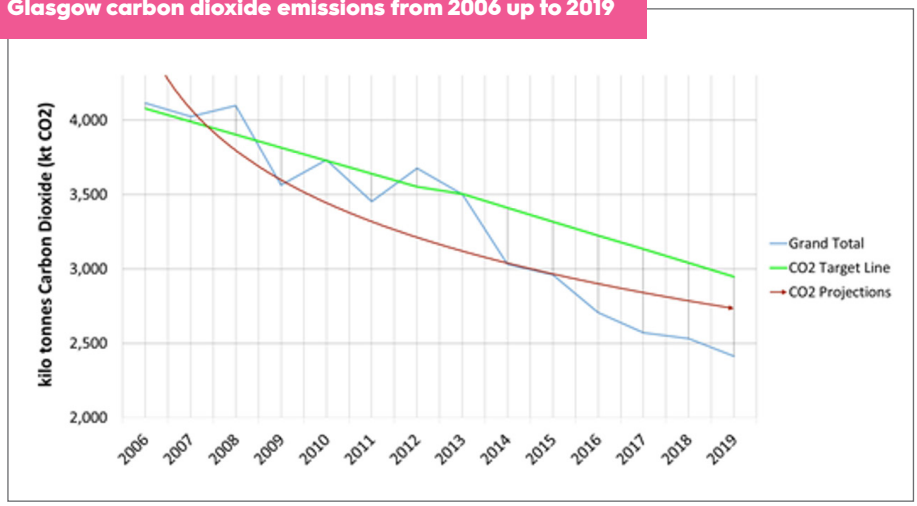


Figure 2. SOURCE: BEIS Glasgow's CO_2 Emissions 2006-2019
Source: Glasgow City Council Energy & Carbon Masterplan Update 2021
www.glasgow.gov.uk/councillorsandcommittees/viewDoc.asp?c=P62AFQDNZLT1Z381NT

Glasgow's Declaration of Climate Emergency

While Glasgow reached its target of reducing CO_2 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.

More information on how Glasgow aims to address the Climate Emergency can be found at: www.glasgow.gov.uk/CHttpHandler.ashx?id=50623&p=0

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.

With over 607,000 confirmed cases in Scotland since the start of the pandemic, the impact of Covid-19 has been widely felt across Scotland and rest of the UK. Close to 140,000 UK citizens have lost their lives due to COVID-19 and the pandemic is not over yet, with some restrictions still remaining in place and cases continuing to fluctuate. The majority of the Glasgow population have now received their first vaccine, with the roll out continuing to the younger age groups at present.

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: www.glasgow.gov.uk/councillorsandcommittees/viewSelectedDocument.asp?c=P62AFQDNDXDXT181T1

Due to changes in lifestyle, working patterns, use of cars, and public transport across the city, the data expected from the project is now likely to be significantly different than initially anticipated, with far less people commuting into the city to work. The full impacts of the pandemic on the project will not be seen until a full analysis has been done of the data sets on completion of the project.

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.

Additional Glasgow Solutions with RUGGEDISED

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.

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.

Image: Unsplash / Fredrika Carlsson

5. 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 are developing 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 is a matter of organisational innovation.

Concrete cases which have been investigated in the current process of developing a business model are:

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 aims to look 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 high rise 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 has been working 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.

Current 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 one) and the University of Strathclyde and Glasgow City Council City

Chambers (Case study two)will not proceed as expected at this time.

The former 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.

In search for alternative applications of the contractual collaboration agreement, a new source of heat is 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.

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. Smart Solution G1 will enable 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. Impacts are likely to be most evident in the future 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.

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.

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

Battery storage to support the integration of electricity generated by Photovoltaics and wind turbines, discharge to electric vehicle chargers, and act as grid balancing mechanism. Technological and business case challenge linked to the physical deployment and connection of battery storage onsite, as well as understanding how energy is purchased from local generators, provided to the battery and sold by the storage provider either to local points of consumption or to provide grid balancing services.

General Description: The Electrical Energy Storage (EES) proposed for implementation within the Duke Street car park has been 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 CO_2 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.

Current implementation stage: The EES is now on site at Duke Street car park. As noted in the first Implementation report from Glasgow, 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 2019. 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. The battery has now been delivered to site and due to be operational in February 2022.

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 canopy 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.

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,

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.

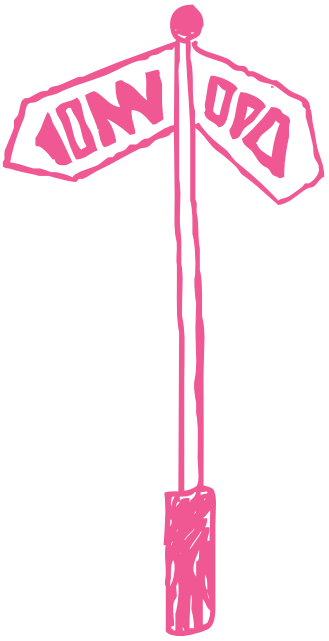
Solution G3: TCB CHP surplus power storage in EV Charging hub battery storage

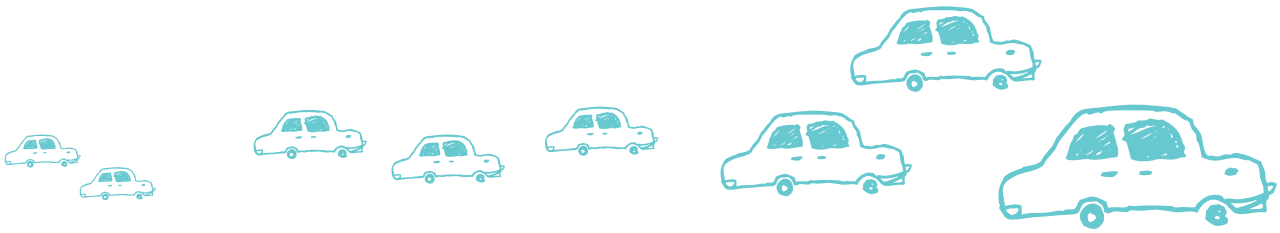
The technological challenge is to have energy distributed from Tennents Caledonian Brewery (TCB) Combined Heat and Power installation (CHP) to battery storage for later use in city systems, such as EV charging. Business model required, both technically and operationally. The former requires the technical 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.

Current implementation status

As noted in G1, Tennents Caledonian Brewery were unable to install a new CHP due to the fault level limit. 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 is due to be installed in the Drygate flats to act as a fuel poverty alleviation measure.

Project partners SPEN 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. It is worth note that the potential to look at business model development is still being explored.





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

This is a technical and business case challenge, in relation to the optimisation of the integration of the near-site Renewable Energy Sources (RES), potentially linked to the battery storage integration of renewable energy sources. This solution seeks to significantly increase the deployment of renewable energy sources in the project district and ensure that as much of the renewable energy generated is used locally within the district.

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 is to maximise the utilization of locally generated renewable energy, with minimal export to the electrical grid, thus minimising the CO_2 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.

Current implementation stage: Initial work on Smart Solution G2 - EV-charging hub battery storage involved extensive modelling by project partners at the Energy Systems Research Unit (ESRU) based at the University of Strathclyde. The outcome of the modelling work shaped the development and deployment of the renewables 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 canopy** was also extensively modelled by the ESRU. It was found that it would support the installation of electric vehicle charge units and building operations whilst having no negative impact on revenue generation from parking and additionally will also provide shelter from the elements to car park users.

This 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. 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 enabled energy generation through solar PV without the loss of any parking spaces. This in turn resulted 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.

Connection to other smart solutions: Smart solution 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.

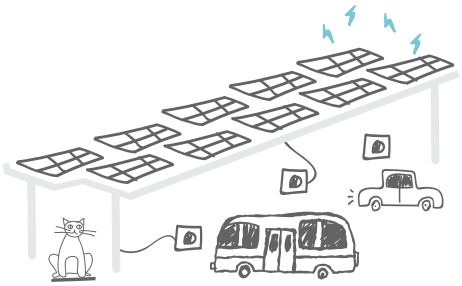
Connection to existing urban system and citizens / users: The solar PV canopy, whilst providing renewable energy for use by electric vehicles, would also provide physical shelter to citizens parking on the top floor of the car park. The availability of the EV chargers, being fed from the renewable energy 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.

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.

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, will 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 will enable taxi companies in the city to switch to using electric vehicles. If successful, this proof of concept will influence the same type of infrastructure to be rolled out to other multi-story car parks. Duke Street car park is also located just off the M8 motor way, and therefore would also allow EV users to stop and charge on longer journeys that pass through the city.

Current implementation stage: Two 50kW charging units have been installed in the car park with funding from project partners Transport Scotland as part of the overall funding package for Glasgow City Council. These have the ability to charge four EV's. 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. Due to the combination of technology to be installed, investigation works found that the electricity supply to the car park was insufficient, therefore the other chargers will be installed at the start of 2020 after upgrade works have been done to the neighbouring substation which are currently underway.

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. The data provided from these charge bays provided by Transport Scotland will allow the data based decision platform (DBDP) to show demand and usage, therefore influencing further roll out of this technology across the city. Further work done on data sharing between Transport Scotland and SPEN to will allow for the design of charging profiles. These profiles will be used to temper the flow of energy.

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. The business case will be developed on the completion of the charging infrastructure install. The remainder of the chargers are due to be installed by February 2020, following an upgrade to the substation. 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 canopy 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. This situation will be monitored and data collected and analysed when the full solution is completed.

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.

Replication assessment: This is a highly replicable solution both across Glasgow, Scotland and the UK. It is worthy of note that travel patterns have temporarily 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.

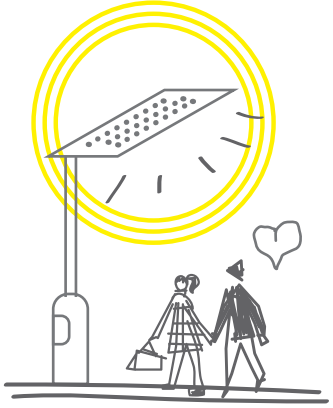
Solution G6: Integrated EV charging functionality in Intelligent LED street lights

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 will serve 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 will be between 3.5 – 7kW as the expectation is that the use will be for businesses or domestic users with long duration parking requirements. The integration of EV charging into the street lighting column will be funded by Transport Scotland and the street lighting will be funded through European Regional Development funding.

Expected Impact: It is expected that the installation of these integrated chargers will 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.

Current implementation stage: The installation of the integrated EV charge points on Collin's Street is now completed.

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, the columns with integrated EV charging will be the last to be done.

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 will be obtained from these will be able to inform 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.

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) and the data will feed in to the newly developed data based decision platform (G7).

Connection to existing urban system and citizens / users: 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, we expect residents use to be 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.

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 will, in 2022, commence 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.

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. 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.

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

Creation of a query based geo-spatial 'Data Based Decision Platform' (DBDP) that will collect data related to city management (e.g. energy, air quality, traffic flow, etc.) and provide analysis of multiple data sets to enhance energy planning in the city. Glasgow City Council will utilise the existing Open Data Platform and build DBDP around existing ICT infrastructure. This is a technical challenge.

General Description: The data based decision platform will pull 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 will 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 will also be used 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 is also 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 will be an important tool to assist in achieving ambitions as a city to become net zero carbon by 2030. More specifically this will help support the roll out and spatial planning of actions to support Glasgow's Climate Plan and the Green Deal

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

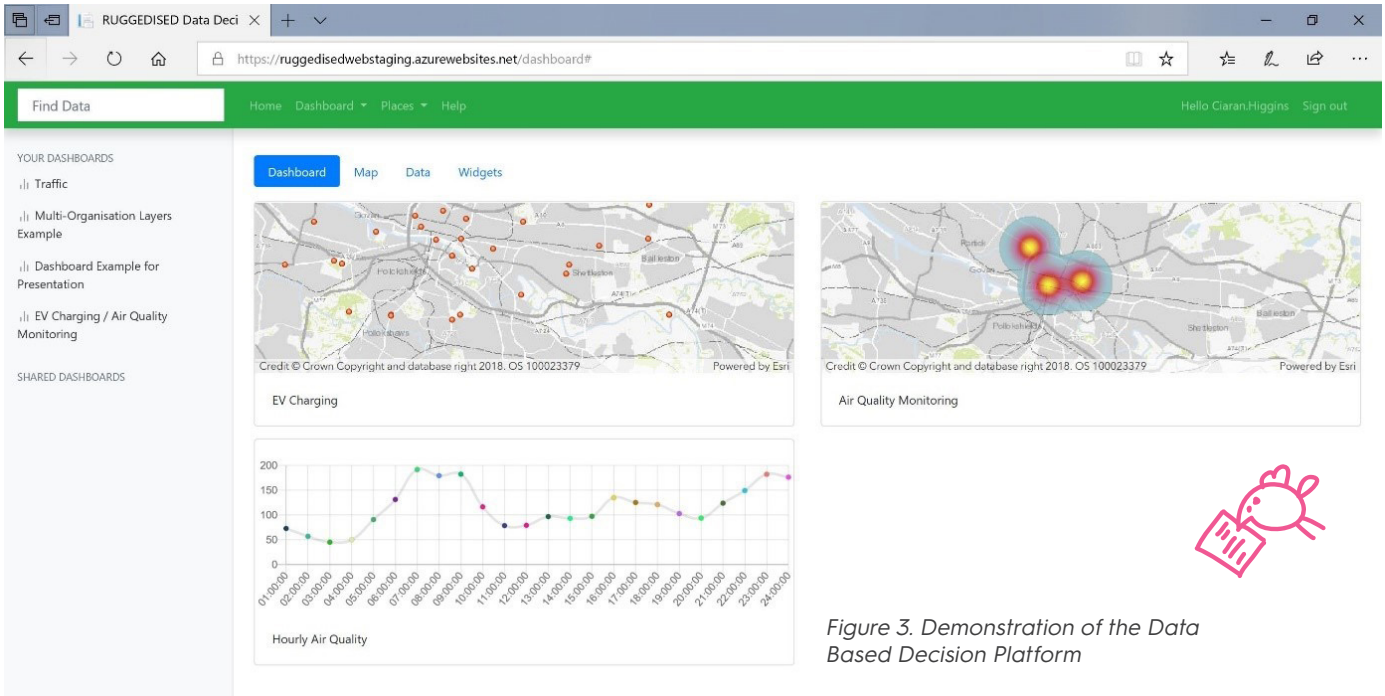


Figure 3. Demonstration of the Data Based Decision Platform

solution developed has a legacy within the council, the tool had to align with the existing GIS product suite and data environment. Many of the tools identified – some of which were open-source – would potentially have to be maintained in-house after the RUGGEDISED project finishes. 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. Because the platform has been developed in house, there is a willingness to share this with other cities across the RUGGEDISED consortium and Europe. The platform also has the capability to pull data from the European Commission and other partner cities, allowing Smart Solutions to be compared.

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.

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 are now being explored. 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. Delays in deployment of some of the smart solutions has also led to the DBDP not being utilised as fully as possible, and this will be fully realised when the installation of all of the hardware has been completed.

Upscaling plans: This solution will not be upscaled as it already exists as a city wide platform. There is however, the potential for replication in other cities. Where relevant, additional datasets will be incorporated into this smart solution.

Replication assessment: 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 replication of all of the other smart solutions. 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.

Image: Unsplash / Giorgio Trovato

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

This solution examines how intelligent LED street lighting can be used in a demand-side management context as part of a 'smart grid'. In addition, it will explore the potential for also controlling connected assets, such as EV's.

General Description: RUGGEDISED will seek 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 will depend upon simple, standardised communications connectivity. RUGGEDISED should inform on the level of DSR achievable from such systems.

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 is also anticipated that the overall carbon reduction from the installation of the intelligent street LED lighting will be around 60%.

Current 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. This smart solution is now in the monitoring and verification phase. The wireless communications network has been installed and allows for transfer of data through the city and to the data based decision platform.

Innovation: 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.

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 is currently underway.

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

Replication assessment: The ISL with smart grid capabilities is already being upscaled and deployed throughout the smart street and the rest of Glasgow. This smart solution has replicability at both a national and international level.

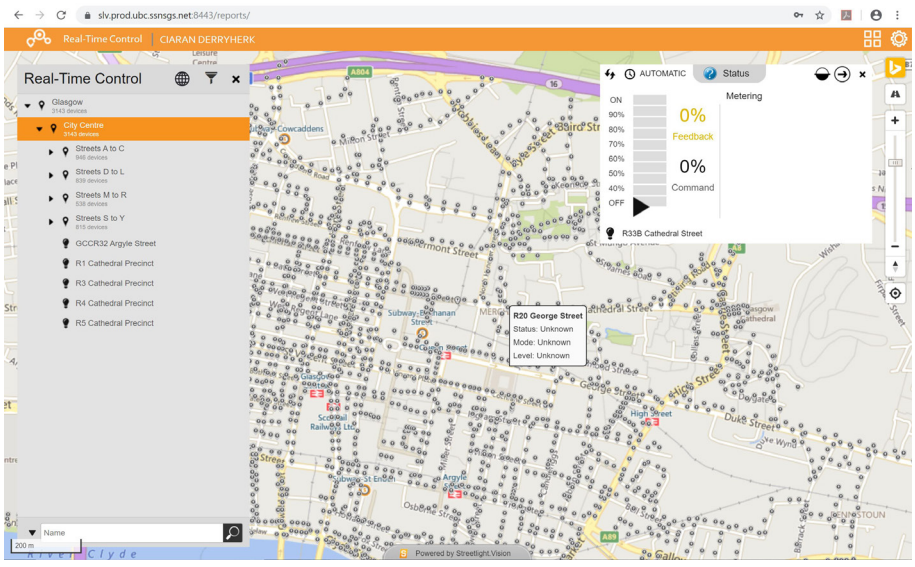


Figure 4. Demonstration of the central management system showing street lighting across Glasgow

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

The challenge is in developing the Central Management System of 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 is achieved in a domestic scenario. This will include exploring the potential to activate cheaper tariffs for residents when renewable generation exceeds demand. The impact of local storage is also being analysed.

General Description: This is a new area that RUGGEDISED will investigate and will 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.

It will also be interesting to understand how the Demand Side Response availability of these properties aligns with or complements that of the non-domestic properties and other assets in the system.

The opportunity to model energy transfer between battery systems and perhaps differential price modelling are other areas of innovation in RUGGEDISED.

Expected impact: It is hoped that the deployment of this 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.

Current implementation stage: 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 will be connected to the CMS and Grid Interface Controller provided by Siemens. Please see appendix 3 for Heriot Watt's updated report on this smart solution.

Innovation: This will be the first trial of this system in Glasgow, where there are large numbers of properties using outdated electric storage heater systems. The aim of this is 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: Data from this solution will be analysed in the Data Based Decision Platform (G7) and communicated via the intelligent street lighting communications network (G8). This solution is also 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.

Results: The platform that manages the battery operated by Heriot Watt University has been producing data since 2021. Monitoring of this solution is still underway with full results expected soon.

Upscaling plans: 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, there is a huge opportunity to upscale this solution if it proves to be the most viable on the market. Due to a large variety of housing stock in the city, it is likely that this solution can be explored in tandem with other solutions such as installing insulation and improving glazing in older properties.

Replication assessment: Due to Glasgow 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.

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 CO_2 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 will seek 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.

Current 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. Work is now progressing with Siemens Italy to enable the controls to be put in place for this solution to be completed.

The modifications to the non-domestic building BMS interfaces will be performed in conjunction with deployment of the DSMc platform.

Innovation: This project builds on a previous project, so the implementation of demand-side management is not new. Connection to the ISL mesh radio, however - a dedicated comms network across the city centre that will be used to control lighting as well as the other controllable loads in the RUGGEDISED project - is novel and, it is hoped, will be a key asset in the future for further Smart City developments in Glasgow. 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.

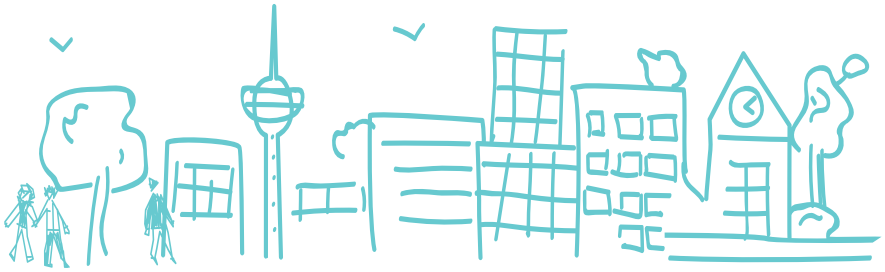
Connection to other smart solutions: Connection to the Intelligent Street Lighting network (G8) and central demand-side management controller.

Connection to existing urban system and citizens / users: There is currently no connection to citizens as it will be a closed system, but the results will be shared. There is a potential also to create a dashboard in the Data Based Decision Platform 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; therefore it may not be possible to do. It will be investigated, however.

Results: This solution is still in progress and has experienced delays due to lack of access because of restrictions in Scotland due to the pandemic.

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.

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.



Disclaimer

Deliverable D4.6,
Implementation Report Glasgow (2/3)

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

Date
05 / 2022

Authors
Glasgow City Council

Contributing authors
Transport Scotland, Scottish Power Energy Networks, The University of Strathclyde, Tennents Brewery, Siemens and the Wheatley Group

Design
unger+ kreative strategen GmbH

Layout
Stephan Köhler (ICLEI)

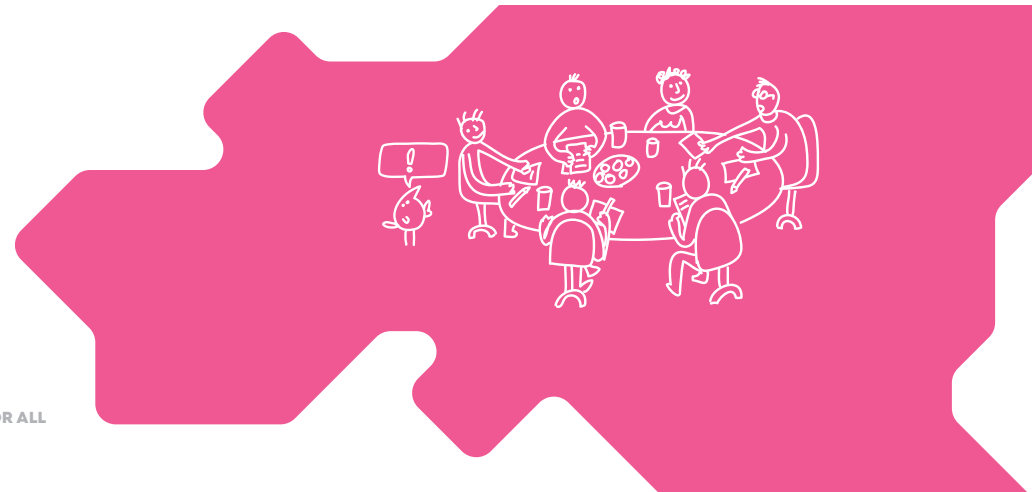
About the project
RUGGEDISED is a smart city project funded under the European Union's Horizon 2020 research and innovation programme. It brings together three lighthouse cities: Rotterdam, Glasgow and Umeå and three fellow cities: Brno, Gdansk and Parma to test, implement and accelerate the smart city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

About the publication
This is the second 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.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731198. The sole responsibility for the content of this document lies with the RUGGEDISED project and does not necessarily reflect the opinion of the European Union.

RUGGEDISED
Designing smart, resilient cities for all

Partners



Designing smart, resilient cities for all

ROTTERDAM . UMEÅ . GLASGOW
BRNO . PARMA . GDANSK

E info@ruggedised.eu
W www.ruggedised.eu
@Ruggedised
Ruggedised EU

Co-funded by the Horizon 2020 Framework Programme of the European Union