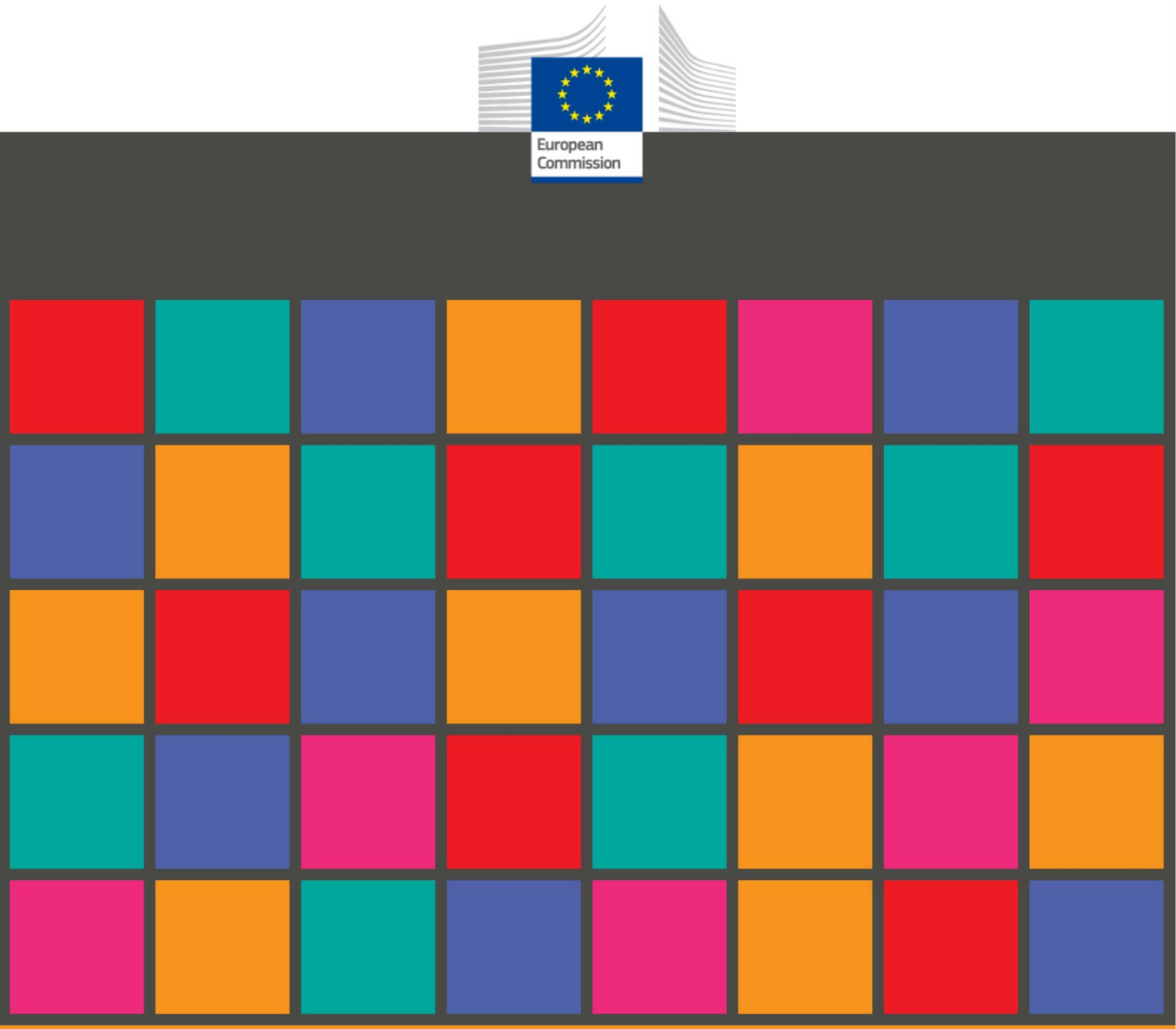

Consolidated analysis and impact assessment of Smart Cities and Communities projects:

SmartEnCity, Sharing Cities, mySMARTLife and RUGGEDISED

Deliverable D4-1-2

AIT Austrian Institute of Technology
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EUROPEAN COMMISSION
European Climate, Infrastructure and Environment Executive Agency
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EUROPEAN COMMISSION

Consolidated analysis and impact assessment of Smart Cities and Communities projects:

SmartEnCity, Sharing Cities, mySMARTLife and RUGGEDISED

Deliverable D4-1-2

European Climate, Infrastructure and Environment Executive Agency (CINEA)
'Support for the Smart Cities and Communities Lighthouse Project Group'

Deliverable

Task no.	T4.1; T4.2
Task name:	Analysis of highlights, results and impacts Joint impact assessment on achieving goals
Task Leader:	AIT
Delivery Date:	23.10.2023
Description:	This report analyses four Smart Cities and Communities (SCC) projects, namely SmartEnCity, Sharing Cities, mySMARTLife, and RUGGEDISED. The report provides a comparative assessment of their impacts on urban development and their roles in advancing the vision of a climate-neutral Europe. The report shows that the SCC projects have significantly contributed to advancing the state-of-the-art in urban innovation, particularly in the areas of energy efficiency, renewable energy, mobility, ICT, citizen engagement, and governance. They have also generated valuable knowledge and data that can support evidence-based decision-making, monitoring, and evaluation of urban policies and strategies. The report identifies some challenges and barriers that need to be addressed, such as the lack of political will, regulatory frameworks, and financial resources to support the replication and upscaling of the projects. It recommends that future research, policy, and practice in the field of smart and sustainable cities should focus on strengthening the linkages between urban innovation and climate action, enhancing the social and environmental sustainability of smart city solutions, and scaling up successful smart city solutions and business models.

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Table of Contents

Executive Summary 8
1. Aim and Scope of the Deliverable 9
1.1. European Smart Cities and Communities projects 10
1.2. Scalable Cities 11
2. Method and Data Sources 12
3. Main Achievements 16
3.1. SmartEnCity 16
3.2. Sharing Cities 20
3.3. mySMARTLife 30
3.4. RUGGEDISED 35
4. Summary of the Main Achievements and Impacts 40
4.1. Key results 40
4.2. Main impacts 42
5. Barriers for a Successful Implementation 44
5.1. Financial and economic barriers 44
5.2. Social and cultural barriers 45
5.3. Technical barriers 46
5.4. Political barriers 47
5.5. Regulatory barriers 47
6. Enabling Factors for a Successful Implementation 49
7. Summary and Outlook 51
Acknowledgement 52
Bibliography 53
Annex 1: Overview of the funding programme and call topics of the SCC projects 55

List of Figures

Figure 2: Methodology 12
Figure 3: Towards the EUR 500 million triggered investment goal 26
Figure 4: Measure / solution opportunities identified & valued 27
Figure 5: Opportunities and values by city/geography 28
Figure 6: Solutions per cluster (SRT) 40
Figure 7: Energy Solutions (SRT) 41
Figure 8: Solutions per cluster and project (Source: SRT) 41
Figure 9: Number of solutions per project (Sources: SRT project websites, project deliverables) 42

List of Tables

Table 1: List of expected impacts of the SCC-01-2015 and SCC-1-2016-2017 10
Table 2: Overview of the different KPI (SRT) 13
Table 3: Overview of the different KPI (Manual) 14
Table 4: Synthesizing of cluster types 15
Table 5: SmartEnCity project description 16
Table 6: SmartEnCity key results 17
Table 7: Sharing Cities project description 20
Table 8: Sharing Cities key results 22
Table 9: mySMARTLife project description 30
Table 10: mySMARTLife key results 31
Table 11: RUGGEDISED project description 35
Table 12: RUGGEDISED key results 36
Table 13 Impact assessment of the four projects 43
Table 14: Websites of Smart Cities and Communities (SCC) projects 52
Table 15: Details of the 18 SCC projects (Source: Cordis) 55

Executive Summary

This report presents a consolidated analysis and impact assessment of four Smart Cities and Communities (SCC) projects, namely **SmartEnCity**, **Sharing Cities**, **mySMARTLife**, and **RUGGEDISED**. The report aims to provide a comparative assessment of their impacts on urban development and their roles in advancing the vision of a climate-neutral Europe. It concentrates solely on the practices, lessons learned, and results from SCC projects that have reached completion between the first consolidated analysis and the second evaluation, as presented in this report.

The report begins by introducing the SCC projects and their objectives, methodologies, and timelines. It then presents the main achievements and impacts of each project, including their key results, project highlights, and main impacts. The report also identifies the barriers and enabling factors for the successful implementation of smart city solutions and business models, including financial and economic barriers, social and cultural barriers, as well as technical, political, and regulatory barriers. It concludes with a summary and outlook chapter that highlights the key findings and lessons learned from the SCC projects and provides recommendations for future research, policy, and practice in the field of smart and sustainable cities.

The report shows that the SCC projects have significantly contributed to advancing the state-of-the-art in urban innovation, particularly in the areas of energy efficiency, renewable energy, mobility, ICT, citizen engagement, and governance. They have demonstrated the feasibility, scalability, replicability, and sustainability of various smart solutions and business models, as well as their potential to enhance the quality of life, social inclusion, and economic growth in urban areas. They have also generated valuable knowledge and data that can support evidence-based decision-making, monitoring, and evaluation of urban policies and strategies. The SCC projects have developed various tools, platforms, and indicators that can help cities measure and benchmark their performance, identify their strengths and weaknesses, and learn from each other's experiences. They have also fostered a culture of collaboration, co-creation, and co-learning among different stakeholders, including citizens, businesses, academia, and public authorities.

The report also identifies some challenges and barriers that need to be addressed, such as the lack of political will, regulatory frameworks, and financial resources to support the replication and upscaling of the projects. It recommends that future research, policy, and practice in the field of smart and sustainable cities should focus on strengthening the linkages between urban innovation and climate action, enhancing the social and environmental sustainability of smart city solutions, and scaling up successful smart city solutions and business models.

1. Aim and Scope of the Deliverable

This report comprehensively assesses the key findings and impacts from the Smart Cities and Communities (SCC) projects, specifically **SmartEnCity**[1], **Sharing Cities**[2], **mySMARTLife**[3], and **RUGGEDISED**[4]. It represents a vital step in evaluating the collective contributions of these projects to the overarching goal of achieving a climate-neutral Europe. This chapter outlines the objectives, scope, and timeline of the deliverable.

The primary objective of this report is to collect, evaluate, and synthesise the findings from the aforementioned SCC projects. It seeks to provide a comparative assessment of their impacts on urban development and their roles in advancing the vision of a climate-neutral Europe.

To ensure a thorough analysis, this report concentrates solely on the practices, lessons learned, and results from SCC projects that have reached completion at the time of writing this report. The focus on completed projects is essential, as they offer a wealth of available data for a comprehensive analysis and impact assessment.

The present version of this report presents an analysis of four SCC projects completed between January 2023 and July 2022, namely SmartEnCity, RUGGEDISED, Sharing Cities, and MYSMARTLIFE. The document aims to consolidate the key findings, results, and impacts of these projects into a coherent report with a focus on (climate) goals, sustainable solutions, and knowledge generated within these projects.

A previous report covered the projects: **REMOURBAN**, **TRIANGULUM**, **GROWSMARTER**, **REPLICATE**, and **SMARTER TOGETHER**.[5]

By 2025, Scalable Cities will produce four reports that provide a holistic overview of the solutions implemented by the SCC projects up to that point.

This report shows the importance of generating knowledge and solutions that can drive urban sustainability and contribute to broader European climate and energy objectives. The forthcoming sections will delve deeper into the specific goals, outcomes, and impacts of the projects SmartEnCity, Sharing Cities, mySMARTLife, and RUGGEDISED.

[1] https://cordis.europa.eu/project/id/691883

[2] https://cordis.europa.eu/project/id/691895

[3] https://cordis.europa.eu/project/id/731297

[4] https://cordis.europa.eu/project/id/731198

[5] Austrian Institute of Technology, 'Consolidated analysis and impact assessment of Smart Cities and Communities projects', European Commission, April 2022.

1.1. European Smart Cities and Communities projects

The Horizon 2020 Framework Programme of the European Union (Horizon 2020) funded a range of Smart Cities and Communities (SCC) projects during the programme period 2014 – 2020. These projects were mainly Innovation Actions (IA) with the aim of bringing together cities, industry, and citizens to demonstrate solutions and business models that can be scaled up and replicated, leading to measurable benefits in energy and resource efficiency, new markets, and new jobs. [1]

An overview of the time frames of the analysis of the 18 Lighthouse projects and the related call programmes are provided in Annex 1: 'Overview of the funding programme and call topics of the SCC projects'.

Horizon 2020 published four calls for proposals in the period 2014 – 2020. The four projects that are the subject of this report were funded under the 2nd call (H2020-SCC-2015) and the 3rd call (H2020-SCC-2016). These calls had a similar focus and scope. The projects aimed at demonstrating solutions at the urban district level while integrating smart homes and buildings, smart grids, energy storage, electric vehicles, and smart charging infrastructures and using the latest ICT platforms based on open specifications.

The scope of the call topic focused on so-called 'Lighthouse cities', cities that are developing and testing integrated innovative solutions at the district scale and that act as an example for replication in other cities. The projects tested technologies that were 'near-to-market' (TRL 7 or higher), innovative business models for large-scale deployment, and enabled replication in follower cities. They needed to include essential aspects such as improving energy efficiency, incorporating renewable energy sources, integrating electric vehicle infrastructure, using open ICT solutions, and developing innovative business models. Expected impacts were increased energy efficiency, higher use of renewables, improved air quality, reduced technical and financial risks, and active cooperation between cities. [2] [3]

The two calls were identical in terms of specific challenges, scopes, and essential aspects. The only difference was in the description of the impact section of the 3rd generation call, where a focus on the security and affordability of local energy systems has been put. In Table 1, a list of the expected impacts of the two calls is presented. The impacts listed will also be considered and reflected in the analysis of the SCC projects in the next sections.

Table 1: List of expected impacts of the SCC-01-2015 and SCC-1-2016-2017

H2020-SCC-01-2015 **SCC projects:** ■ SmartEnCity ■ Sharing Cities	**H2020-SCC-1-2016-2017** **SCC projects:** ■ Ruggedised ■ mySMARTLife
■ Deploy wide-scale, innovative, replicable and integrated solutions in energy, transport, and ICT; ■ Trigger large-scale economic investments with the repayment of implementation costs in acceptable timelines (to facilitate the bankability of the projects); ■ Increase the energy efficiency of districts and of cities, and foster the use of renewables and	■ Put into practice a bankable solution for a challenge identified by the city; ■ Increase the energy efficiency on a district scale; ■ Increase significantly the share of renewable energies, their integration into the energy system, stimulate self-consumption, and reduce curtailment to the minimum; ■ Increase local air quality;

their integration into the energy system, and enable the active participation of consumers; ■ Increase mobility efficiency with lower emissions of pollutants and CO_2; ■ Reduce the energy costs; ■ Decarbonise the energy system while making it more secure and stable; ■ Create stronger links between cities in Member States with various geographical and economic positions through active cooperation. It is envisaged that the proposals will also bring societal benefits: ■ Reduce energy bills for all actors, and especially citizens and public authorities; ■ Increase quality of life by creating local jobs (that cannot be delocalised) in cities; ■ Improve air quality.	■ Reduce the technical and financial risks in order to give investors confidence in investing in large-scale replication; ■ Make the local energy system more secure, more stable, and cheaper for the citizens and public authorities; ■ Ensure the roll-out of electric vehicles in cities while containing the need for excessive upgrading of the electricity grid; ■ Reduce transport-based CO_2 emissions on the basis of the CO_2 intensity of the European electricity grid of 540 CO_2/kWh (coherent with the TEST format - available on the Participant Portal); ■ Create stronger links and active cooperation between cities in a large number of Member States with a large coverage of cities with different sizes, geography, climatic zones, and economic situations.

1.2. Scalable Cities

The role of Scalable Cities is to identify and promote solutions and business models that can be scaled up and replicated across Europe and lead to measurable outcomes such as new jobs and energy savings. Scalable Cities represents 120 cities that are involved in 18 Smart Cities and Communities projects funded by Horizon 2020 with around EUR 345 million. Working in consortia with academia, industry, associations, and consultants, they implement more than 550 demonstrations of technological and social innovations.

2. Method and Data Sources

The aim of this consolidated analysis is to show how the Smart Cities and Communities (SCC) projects have helped cities increase their energy and resource efficiency, use local renewable energy sources, and reduce greenhouse gas emissions based on their specific local circumstances with these solutions.

SCC projects are mandated to monitor and report their impacts, focusing on technical performance, energy savings, carbon emissions reduction, technology costs, and job creation. However, a consolidated dataset illustrating the collective impact of SCC projects is currently unavailable. For this report, a methodology has been developed to assess the impact using standardised data from the SCC projects, encompassing increased energy efficiency and renewable energy uptake across energy, mobility, and ICT sectors. The standardised data is sourced from the SCC's dedicated database, the SRT.

There are two parts to the impact analysis. Solutions having measurable outcomes should be reported in the Smart Cities Marketplace's self-reporting tool (SRT). This database collects data on the outputs and impacts of the EU-funded demonstration projects on smart cities and energy-efficient buildings. In the first step, this report uses the SRT to analyse the impact and outcome of the carried-out SCC projects and their contribution to the EU climate goals. A second analysis was done with the reports and deliverables found on each project website.

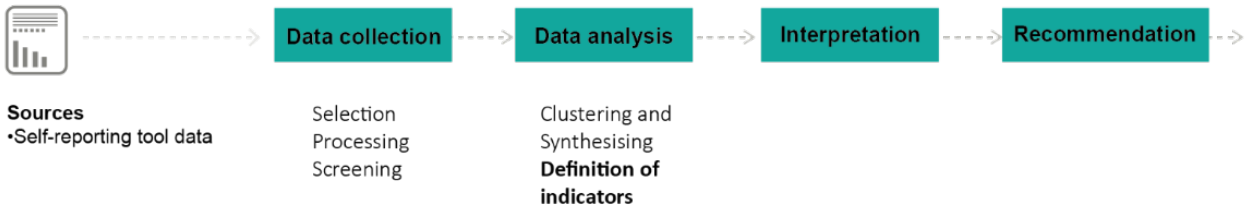

Figure 1: Methodology

Firstly, the data was collected after screening the SRT. The data from the SRT is publicly available. The preparations necessary to gather the information on the SRT are described on the website [4]. Next, project websites, reports, and deliverables were scanned to find relevant data.

Secondly, relevant KPIs were selected. In this case, relevant KPIs are those that measure the impact of the implemented solutions on the EU climate goals. The KPIs identified as appropriate are listed below in "Definition of Indicators". To analyse the Excel file and standardise the solutions, they were clustered. This process is described below in "Data Collection Approach". The clustering was standardised in the SRT clusters, mobility, energy, and ICT (see Table 4). This clustering should not exclude any solutions. An Excel analysis was then done in the form of a pivot table to clarify the data. This approach did not include a sufficient number of data sets, and therefore the second analysis was done. For the data selected from project websites, KPIs were selected based on comparability since only a few data sets were comparable across projects. These were then also clustered and summarized. Unlike in the rest of the report, in this section, all closed projects are analysed, not just those from the last period.

Depending on the solutions, cities measure the outcome of the implemented solutions with different indicators. Table 2 gives an overview of the reported KPIs in the SRT from the closed SCC projects:

Table 2: Overview of the different KPI (SRT)

EU key targets (Based on the climate and energy framework)	**KPIs** (SRT)[42]	**Description**	**Unit**
CO_2 emissions	Total annual CO_2 emission savings	Based on baseline data the CO_2 Emission savings for each solution was calculated.	$kgCO_2/y$
Share of renewable energy	Total share of local renewable energy in the local energy mix	The KPI shows the percentage of the renewable energy in the local energy mix	%
Energy efficiency	Final annual energy savings ■ Final energy demand of electricity ■ Final energy demand of cooling ■ Final energy demand of domestic hot water ■ Final energy demand of space heating	Based on baseline data the final energy savings for each solution was calculated.	$kWh/m^2/y$
Additional targets	Number of people involved ■ Number of people with increased ability to manage their energy consumption ■ Number of end users involved ■ Social citizens involved ■ New building social citizens involved	Shows how many people were involved in the process or using the implemented solutions.	#
	Jobs created	Shows how many jobs are created through the solution.	#
	Grants	Shows how much funding was used to implement the solution.	EUR

In this second table (Table 3), the indicators used based on project websites are listed:

Table 3: Overview of the different KPI (Manual)

EU key targets (Based on the climate and energy framework)	**KPIs** (project websites)	**Description**	**Unit**
CO_2 emissions	Total annual CO_2 emission (savings)	Based on baseline data the CO_2 Emission savings for each solution was calculated.	$kgCO_2/y$
Share of renewable energy	Total share of local renewable energy Number of charging stations	The KPI shows the percentage of the renewable energy production of the solution.	% or kWh/y #
Energy efficiency	Final annual energy savings ▪ Due to retrofitting	Based on baseline data the energy savings for each solution was calculated.	kWh/y
Additional targets	Number of people involved ICT users	Shows how many people were involved in the process or using the implemented solutions.	#
	Jobs created	Shows how many jobs were created through the solution.	#
	Grants	Shows how much funding was used to implement the solution.	EUR

The impact assessment on the EU climate goals uses data sets collected from the SRT of the Smart City Marketplace and from project websites and publications. Then, the numbers were aggregated, showing the overall CO_2 and energy savings of the SCC projects per project and clustered in three categories: Energy, mobility, and ICT.

Table 4: Synthesizing of cluster types

CATEGORIES FROM THE SRT (_CLUSTER_TYPE_)	CLUSTER-TYPE
Infrastructure Vehicles	Mobility
ICT	ICT
Boiler DHC-extension Electrical storage New buildings Photovoltaic power plants Refurbished buildings Sorption chiller Waste-heat	Energy

It was not possible to calculate the entire contribution to the climate targets using the PIVOT-Table statements. So, the same process was done with the project website and publications to have more viable information.

To visualise the aggregated results, the excel file was prepared, e.g., single solutions and calculations were excluded, and the table visualised the archived results per project as well as at the cluster level. After the preparation of the excel-document the archived results were described.

In addition, data was generated and collected through a literature review and screening of the project and the European Commission websites. Final reports, solution fact sheets, and other deliverables from the project websites of the SCC projects were analysed to find data. The data reported to the SRT was checked against the data collected on project websites.

3. Main Achievements

3.1. SmartEnCity

Table 5: SmartEnCity project description

Project	Focus fields / Aim	Lighthouse Cities	Follower Cities
SmartEnCity (Feb 2016 – July 2022)	The project aimed at creating more sustainable and inclusive Smart Zero Carbon Cities while improving citizens lives, creating jobs, and offering equal growth opportunities. This approach ensured that not only technological solutions were implemented but soft factors, such as quality of life and acceptance of the citizens, were recognised as well. The main goals were to reduce energy demand and increase the renewable energy supply by: ■ Building retrofitting ■ Clean transport systems ■ ICT and raising awareness ■ Use of local sources	Victoria-Gasteiz (ES) Tartu (EE) Sønderborg (DK)	Lecce (IT) Asenovgrad (BG)

The SmartEnCity project, completed in July 2022, primarily aimed to create more sustainable and inclusive Smart Zero Carbon Cities **in small and medium-sized cities** (10,000 inhabitants). This endeavour aimed to enhance the lives of citizens, generate employment opportunities, and provide equal growth prospects. Unlike many other projects, SmartEnCity took a comprehensive approach by recognising not only the importance of technological solutions but also the softer factors affecting urban development.

The key goals of this project were to reduce energy demand and increase the supply of renewable energy. This was achieved through various means, including building retrofitting, the development of clean transport systems, the utilisation of information and communication technology (ICT) for raising awareness, and the use of local energy sources.

The project focused on both "Lighthouse Cities" and "Follower Cities." In the role of Lighthouse Cities, Victoria-Gasteiz in Spain, Tartu in Estonia, and Sønderborg in Denmark led the way in implementing these innovative strategies, serving as examples for other cities. The Follower Cities, which included Lecce in Italy and Asenovgrad in Bulgaria, benefited from the experiences and insights gained in the Lighthouse Cities and adapted these strategies to their unique urban contexts.

In summary, SmartEnCity aimed to improve energy efficiency and create urban environments that were more sustainable and responsive to the needs of their citizens. Concentrating on the quality of life and community acceptance sets the stage for a more sustainable, inclusive, and prosperous future for cities.

3.1.1. Key results

Table 6: SmartEnCity key results

PROJECT	SOLUTION CLUSTER	KEY RESULTS
SmartEnCity [6]	Energy	■ **1,847 dwellings** and **124,506 m²** were retrofitted ■ Energy savings of about **27 million kWh/y** ■ CO_2 reduction of **20,622 tonnes/y** ■ Aesthetic improvement of neighbourhoods ■ Better comfort in the indoor environment
	ICT	■ Monitoring tool for municipal buildings ■ Portal to collect city, building and apartment-level data on the same platform.
	Mobility	■ **13 electric busses** ■ **104 biogas busses** were introduced ■ **29 e-mobility charging points** were made accessible to the public, including old batteries used for energy storage ■ Enabling **two biogas plants** ■ **6 e-Bikes** and e-bike sharing systems

The SmartEnCity project has yielded significant results in various key solution clusters, contributing to developing smart and sustainable urban environments. Here are the noteworthy outcomes of the project:

Energy (Building Retrofitting)

One of the primary focuses of the SmartEnCity project was building retrofitting. Through this effort, 1,847 dwellings and 124,506 square metres of building space were retrofitted. This led to substantial energy savings, estimated at about 27 million kilowatt-hours per year. Additionally, the project achieved a remarkable reduction in carbon dioxide emissions, with approximately 20,622 tonnes per year being eliminated. Beyond the quantitative benefits, the project also brought about aesthetic improvements in neighbourhoods and enhanced the comfort of indoor living environments.

ICT (Smart City Platforms)

In the realm of Information and Communication Technology (ICT), the project introduced several innovative solutions. Notably, a monitoring tool for municipal buildings was established, enabling efficient management and data collection. The project also created a portal that aggregated data at the city, building, and apartment levels on a single platform. This data integration approach enhanced the city's capacity to gather and analyse valuable information.

Mobility (Electric Mobility)

SmartEnCity's endeavours in mobility have made significant strides towards sustainable transportation. The project introduced 13 electric buses, promoting eco-friendly public transportation. Furthermore, 104 biogas buses were integrated into the transportation network, reducing reliance on fossil fuels. To facilitate electric mobility, 29 e-mobility charging points were made accessible to the public. A notable innovation

[6] Data source: https://smartencity.eu/about/lighthouse-cities/

was the utilisation of old batteries for energy storage at these charging points. In addition, the project enabled the operation of two biogas plants, contributing to renewable energy generation. To promote sustainable personal mobility, the project introduced six e-bikes and e-bike sharing systems, further enhancing the city's transportation options.

These remarkable results underscore the SmartEnCity project's commitment to creating sustainable, energy-efficient, and liveable urban environments. By addressing crucial aspects of energy, information technology, and mobility, the project has not only reduced environmental impact but also improved the quality of life for residents. SmartEnCity has indeed made significant strides in paving the way for smarter and more sustainable cities.

3.1.2. Project Highlights

Sønderborg: Solar Cells with Battery Storage

Solar cell plants were installed on the roofs of housing associations in Sønderborg. At first, the generated energy was sold to the public grid but later used for buildings due to the low selling price. Instead of a connection to the grid, a solar cell solution with battery storage was used. This allowed energy stored during the day to be used in the afternoon or evening, which provided significant cost savings. This solution included three social housing associations with more than 20 departments and 18 projects completed.

Tenants in housing departments had the opportunity to decide independently whether to implement the battery solution. The engagement and approval of tenants were crucial aspects of the project's success. Despite a higher initial investment (6-70% more than a direct grid connection), the overall cost was balanced out by the considerable savings achieved through the efficient use of solar energy, with an estimated payback period of 10-12 years.

Impacts

- Installation of 2,500m² of solar panels connected to batteries
- Installed battery capacity of 2 MWh
- Energy savings of about 2,950 MWh per year
- CO_2 reduction of 1,250 tons per year

Sources

- SmartEnCity and Steinbeis Zentrum, 'The Journey towards Zero Carbon E missions – A Travel Guide for Cities', 2021. Accessed: Sep. 28, 2023. [Online]. Available: https://SmartEnCity.eu/media/sec_broschur_rz_2021_ds-web_high_1.pdf Solar cells with battery storage in housing associations / SmartEnCity.eu
- A. Garrido et al., 'Deliverable 7.13 - Evaluation: Assessment of the overall performance', SmartEnCity, 2022. [Online]. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5fe1371da&appId=PPGMS

Tartu: LED Lights with Smart Controllers

In Tartu, Estonia, Cityntel OU developed a smart street light control system utilising wireless mesh technology. The system was composed of smart controllers within 312 LED streetlights, communicating wirelessly with sensors. This solution diverges from conventional approaches where control commands come from a central server or network controller. Instead, operational rules were stored within each luminaire controller, enabling localised decision-making based on local weather and traffic conditions.

The smart street light system includes a range of sensors, such as PIR (passive infrared sensor) movement detectors, movement detectors with cameras, light reflection sensors, noise sensors, and environmental sensors. The objective was to reduce energy consumption, maintenance costs, carbon emissions, and light pollution while extending the luminaire's lifetime. The smart street light solution in Tartu is highly replicable and could be quickly deployed on a large scale, providing immediate savings and reducing the payback period for LED luminaires. Furthermore, its success could lead to the adaptation of similar smart city innovations, such as smart parking, traffic management, and waste management.

Impact

- 320 streetlight controllers were installed
- Significant energy savings (73%) and improved efficiency
- Total energy savings of 142,309 kWh per year

Source

- SmartEnCity, 'LED lights with smart controllers (Tartu) / SmartEnCity.eu'. Accessed: Oct. 16, 2023. [Online]. Available: https://SmartEnCity.eu/about/solutions/led-lights-with-smart-controllers-tartu/

Vitoria-Gasteiz: Retrofitting Package

The building renovation intervention in Vitoria-Gasteiz focused on retrofitting building envelopes, including facade and roof improvements, enhanced insulation, airtightness, and the installation of low-energy windows. The Coronación neighbourhood, selected due to its vulnerability in various aspects, presented significant challenges in retrofitting and implementing smart city concepts due to its high density, diverse income levels, and social dimensions. A total of 27 residential and tertiary buildings were involved in the project, targeting ambitious energy savings. The retrofitting interventions were facilitated through a unique business model where VISESA, a public housing company, acted as a delegate promoter, managing, contracting, and financing rehabilitation works on behalf of home communities. Citizen engagement played a crucial role, with involvement from various associations emphasising community engagement throughout the project. The retrofitting resulted in increased property values, improved health and quality of life, enhanced energy efficiency, lower energy bills, reduced carbon emissions, increased comfort, social integration, job creation, and behavioural change. The successful management of renovation processes, citizen engagement practices, and regulatory and contracting strategies implemented in Vitoria-Gasteiz within the SmartEnCity project provides a valuable foundation for replication in other cities facing similar challenges with building stock thermal performance.

Impacts

- In 2021, there was a consumption of 472 MWh of energy and savings of 150 tCO_2 equivalents – which is equivalent to a 90% reduction in greenhouse gas emissions
- Savings of up to 50% savings of heating costs, with initial consumption at 57.99 kWh/m²year in 2016, and a final consumption of 30.48 kWh/m²year in 2022
- 20% reduction in household energy bills, with costs decreasing from EUR 149.74 per dwelling before the reduction to EUR 109.93 afterwards. Improved energy certifications for renovated properties
- 26 buildings were retrofitted and connected to a new biomass district heating network
- Improved aesthetics of the neighbourhood and increased property values
- Enhanced comfort in dwellings, efficient use, and control enabled by monitoring systems
- Extension of the new district heating network to other buildings and installations in the neighbourhood
- Valuable lessons learned in citizen engagement and empowerment

Source

- SmartEnCity, 'Vitoria-Gasteiz retrofitting package / SmartEnCity.eu'. Accessed: Oct. 16, 2023. [Online]. Available: https://smartencity.eu/about/solutions/vitoria-gasteiz-retrofitting-package/
- European Commission, 'Deliverable 7.13 - Evaluation: Assessment of the overall performance WP7, Task 7.5'. Accessed: Jan. 29, 2024 [Online]. Available: Documents download module (europa.eu)

3.1.3. Main Impacts

The SmartEnCity project had a remarkable and far-reaching impact on energy efficiency and climate sustainability within urban environments. By focusing on the retrofitting of 1,847 dwellings and a total building space of 124,506 square metres, the project achieved significant milestones. These improvements translated into tangible benefits for at least 29,300 inhabitants living in the project's targeted areas.

One of the standout achievements of the project was the substantial reduction in energy consumption. The annual energy savings, estimated at approximately 27 million kilowatt-hours, represent a substantial step towards a more sustainable and energy-efficient urban landscape. This translated to not only lower energy bills for residents but also a decreased reliance on non-renewable energy sources, contributing to a more eco-friendly and economically sustainable future.

Moreover, the SmartEnCity project made a substantial impact on reducing carbon emissions. The project's efforts resulted in an impressive annual reduction of 20,622 tonnes of CO_2 emissions. This environmentally significant achievement reflects the project's commitment to combating climate change and promoting greener urban living.

In summary, the SmartEnCity project's focus on building retrofitting has led to substantial energy savings and a remarkable reduction in carbon emissions. The project's results improved the quality of life for thousands of inhabitants and contributed to a more sustainable and environmentally responsible urban environment. SmartEnCity stands as a commendable example of how focused efforts can drive positive change and create more energy-efficient and climate-friendly cities.

3.2. Sharing Cities

Table 7: Sharing Cities project description

Project	Focus fields / Aim	Lighthouse Cities	Follower Cities
Sharing Cities (Jan 2016-Dec 2021)	Sharing Cities addressed urban challenges, such as energy use, low carbon transport and buildings, and collecting data. Planned around the needs of the people, this project tested ten different technologies to reduce carbon emissions, improve energy efficiency and encourage citizen engagement. Sustainable behaviours were incentivized through rewards. The project had four underlying objectives: ■ Prove that smart city solutions can be integrated into a complex urban environment. ■ Adopt a digital-first approach through ICT ■ Accelerate the market to ease transformative processes in cities	Lisbon (PT) London (UK) Milan (IT)	Bordeaux (FR) Burgas (BG) Warsaw (PL)

Project	Focus fields / Aim	Lighthouse Cities	Follower Cities
	■ Encourage citizen engagement to improve capacity for policy-making		

The Sharing Cities project addressed critical urban challenges related to energy use, low-carbon transportation, energy-efficient buildings, and data collection. Designed with a focus on meeting the needs of urban residents, this innovative project served as a testing ground for ten different technologies, all aimed at reducing carbon emissions, enhancing energy efficiency, and fostering citizen engagement. An integral component of this initiative involved incentivizing sustainable behaviours through rewards, further promoting a sustainable and environmentally conscious urban lifestyle.

The project was underpinned by four primary objectives: Prove Smart City Integration, a Digital-First Approach, Market Acceleration and Citizen Engagement.

Prove smart city integration

One of the fundamental goals was to demonstrate that smart city solutions could be seamlessly integrated into the complexity of urban environments. This demonstrated the feasibility of implementing advanced technologies within the existing fabric of cities to address their pressing challenges.

Digital-first approach

The Sharing Cities project adopted a "digital-first" approach, leveraging Information and Communication Technology (ICT) to drive innovation and transform urban services. This approach was pivotal in optimising resource use and enhancing the quality of urban life.

Market acceleration

Another core objective was to expedite the transformation processes in cities by accelerating the adoption of smart and sustainable solutions. This not only benefits urban environments but also contributes to more efficient and effective urban management.

Citizen engagement

Encouraging active citizen engagement was a key focus. By involving residents in decision-making processes and garnering their input, the project aimed to enhance the capacity for informed policymaking. This approach fosters a sense of ownership and participation in the development of their cities.

The project was implemented in six cities, including Lisbon (Portugal), London (United Kingdom), and Milan (Italy), which served as the Lighthouse Cities and played a pivotal role in testing and showcasing the project's innovations. Additionally, the Sharing Cities project extended its impact to Follower Cities, including Bordeaux (France), Burgas (Bulgaria), and Warsaw (Poland), where the lessons learned, and successful practices were shared and adapted to further urban transformation.

In summary, the Sharing Cities project was a forward-thinking initiative that addressed urban challenges while embracing technology, sustainability, and citizen engagement. It demonstrated that smart solutions can be seamlessly integrated into urban environments, providing valuable insights and lessons for cities worldwide on transforming and enhancing urban living.

3.2.1. Key results

Table 8: Sharing Cities key results

PROJECT	SOLUTION CLUSTER	KEY RESULTS
Sharing Cities [7]	Energy	■ **6,766 m²** of public buildings retrofitted ■ **16 buildings** retrofitted with energy efficiency measures saves **1,713 tonnes of CO_2/y.** ■ **6,124,500 kWh/y** decrease in building energy needs
	Mobility	■ **160 electric vehicles** in a sharing system ■ **244 charging points** ■ **150 e-bikes and 14 new stations** for the sharing system ■ **4,514 tonnes of CO_2 emissions** saved as a result of shared mobility measures
	ICT	■ Introduction of an **Urban Sharing Platform** in all three cities ■ **2,400 Smart Lampposts** are upgraded with smart features

The Sharing Cities project has delivered significant and transformative results across various key solution clusters, leaving a lasting impact on the urban landscape. Here are the noteworthy outcomes of this initiative:

Energy

Under the energy solution cluster, the project focused on retrofitting public buildings. The project successfully retrofitted an impressive area of 6,766 square metres of public buildings. The retrofitting of 16 buildings with energy efficiency measures resulted in a reduction of 1,713 tonnes of CO_2 per year and decreased the building energy needs by 6,124,500 kWh/y.

This renovation not only improved the energy efficiency of these structures but also contributed to a substantial reduction in energy consumption, aligning with the project's goal of fostering sustainability and lowering carbon emissions.

Mobility

The project also made substantial strides in the realm of mobility. The introduction of a sharing system for electric vehicles was a pivotal achievement. This system encompassed a fleet of 160 electric vehicles, providing sustainable transportation options for urban residents. Implementing shared mobility measures has led to a significant reduction of 4,514 tonnes of CO_2 emissions. To support this initiative, the project also established 244 charging points to ensure convenient access to charging infrastructure. Furthermore, 150 e-bikes were integrated into the urban landscape, along with the introduction of 14 new stations for the sharing system. This comprehensive approach to mobility not only reduced carbon emissions but also offered convenient, eco-friendly alternatives for urban transportation.

[7] Data source: https://cordis.europa.eu/project/id/691895/reporting

ICT

In the domain of Information and Communication Technology (ICT), the Sharing Cities project introduced an Urban Sharing Platform in all three cities involved in the initiative. This platform served as a central hub for collecting, managing, and disseminating valuable data related to the project's objectives. It played a crucial role in facilitating communication and coordination among stakeholders, thereby enhancing the effectiveness of the project's implementation.

Also, 2,400 smart lampposts have been upgraded with smart features to facilitate the energy management of mobility and environmental monitoring.

In summary, the Sharing Cities project's remarkable achievements across energy, mobility, and ICT solution clusters have laid the foundation for a more sustainable and forward-thinking urban environment. By focusing on energy-efficient building retrofitting, the introduction of electric vehicle sharing systems, and the deployment of an Urban Sharing Platform, the project has significantly improved the quality of life in the participating cities. These achievements reflect the commitment of the Sharing Cities project to fostering environmentally responsible and technologically advanced urban living.

3.2.2. Project Highlights

Lisbon: Retrofitting of Public Buildings

Two service buildings were renovated. A total of 6,766 m² of floor space in public buildings was retrofitted, including the Lisbon City Hall in the heart of the historic area and an elementary school.

Lisbon City Hall

The Lisbon City Hall is a classified heritage building and has several limitations due to existing regulations. The solution showed how architectural integrity and historic buildings did not have to be destroyed to increase energy efficiency.

The selection of solutions for the Lisbon City Hall involved navigating challenges such as conflicting priorities, budget constraints (high investment costs), building requirements, and environmental goals. The focus was primarily on enhancing efficiency while considering historical and architectural constraints. Notable solutions included restoring windows, upgrading the HVAC system, transitioning to LED lighting, and installing a photovoltaic solar panel system. Approval from the National Directorate General for Cultural Heritage was crucial, leading to specialised techniques for window restoration and careful consideration of PV panel placement to preserve panoramic views and respect cultural heritage regulations. Despite the complexities, a collaborative agreement was achieved through a thorough and adaptive licencing process.

EB1 Engenheiro Duarte Pacheco elementary school

The school's retrofitting focused on the evaluation from a community perspective. The primary goal of the intervention at EB1 Engenheiro Duarte Pacheco elementary school was to enhance working conditions and the overall physical and visual quality of the school environment. The focus was on optimising thermal and acoustic comfort by adapting various building elements, spaces, and intended uses to achieve improved conditions for the students and staff.

Impacts

- Reduction of 1,399,265 kWh/y and 597 tCO_2/y saved through retrofitting buildings
- Deep energy-efficiency retrofit of historic Lisbon city hall leads to 36% energy savings and 50% reduction in electricity usage from the grid.
- Window refurbishment to reduce thermal leaks
- PV panels were installed after approval by the Cultural Heritage Association.

- LED lighting installation
- Smart meters and energy management were integrated
- Replication: 200 private and public buildings are retrofitted in Burgas

Source

- Sharing Cities, 'Smart booklet. Retrofit of publicly owned buildings. Services buildings', 2020. Accessed: Oct. 16, 2023. [Online]. Available: https://sharingcities.eu/wp-content/uploads/sites/6/2022/07/2020_Booklets_Buildings_retrofit_public_owned_Final.pdf

Lisbon, Milan and London: EV Sharing Model

The deployment of the sharing model of EVs in the cities of the Sharing Cities project is aimed at promoting sustainability and enhancing urban life quality. In Milan, a pioneering electric vehicle (EV) sharing model is being trialled within a condominium, fostering community EV usage. Lisbon has procured 160 EVs and introduced smart parking technologies, emphasising EV integration and proper parking management. Meanwhile, Greenwich is integrating EVs into daily operations through a back-to-base model and a forward-thinking car-sharing initiative, prioritising sustainable transport and smart parking solutions. These initiatives reflect a concerted effort to balance financial, environmental, social, and economic considerations in fostering a cleaner and more efficient urban landscape.

Impacts

- Across the cities 1,600 e-vehicles have been deployed
- 244 charging points in Milan
- Commitment to expand Milan's mobility areas to 43 locations city-wide (metro-regional level)
- Replication:
    - 500 e-cars available under a scheme with the city of Warsaw
    - Three climate-friendly parking lots in Warsaw

Source

- Sharing Cities, 'Smart booklet. Electric vehicle sharing schemes. E-car sharing Smart parking E-Vehicle Charging Points', 2020. Accessed: Oct. 16, 2023. [Online]. Available: https://sharingcities.eu/wp-content/uploads/sites/6/2022/07/2020_Booklets_EV_sharing_Final2.pdf

Lisbon: Sharing Lisboa App

In Lisbon, Portugal, the development of Sharing Lisboa, a Digital Social Market (DSM), was initiated. This platform, accessible through a mobile application (APP), enables the sharing of goods and services, promoting community collaboration to champion a collective cause. The project entailed a competition among three schools for the academic year 2018/2019, encouraging active participation from the school and neighbouring communities, all striving to achieve a final prize.[7]

The Sharing Lisboa app is an innovative tool developed through a co-design process using design-thinking methodologies within the Lisbon consortium. The development involved extensive community feedback and collaboration with beta-testers to refine the app and its features. The app encompasses various components, including integration with external accounts to monitor behaviour, a participant history page to track progress and contributions, a common causes page to monitor schools' involvement, thematic quizzes to educate and engage participants, and a reward partners page showcasing offers from a network of shops. The app has the potential to foster synergies across different layers of society, engaging citizens, companies, and state entities. It's designed to be customizable based on individual preferences, making it

a powerful tool for behaviour change and city improvement. Sharing Lisboa integrates with existing systems and platforms for communication, dissemination, and education, encouraging data sharing among participants, whether they are residents or tourists.

Impacts

- 1,260 users were registered, collecting more than 850,000 points through approx. 17,000 transactions.
- EUR 20,000 were awarded to the school 'Escola Básica de 2,3 de Nuno Conçalves' in Lisbon to invest in 'eco-interventions' at their school for energy savings via the Sharing Lisboa app.

Sources

- Sharing Cities, 'Smart booklet. Digital Social Market Designing services which enhance connections between cities and citizens'. Accessed: Oct. 16, 2023. [Online]. Available: https://sharingcities.eu/wp-content/uploads/sites/6/2022/07/2020_Booklets_DSM_Final2.pdf
- C. C. Rolim and P. Baptista, 'Sharing Lisboa: A Digital Social Market to Promote Sustainable and Energy Efficient Behaviours', Climate, vol. 9, no. 2, p. 34, Feb. 2021, doi: 10.3390/cli9020034.

3.2.3. Main Impacts

The Sharing Cities project has left a profound impact on both energy efficiency and climate sustainability, yielding a range of substantial benefits that have contributed to a greener and more environmentally responsible urban landscape. Here are the significant energy and climate-related achievements of this Smart Cities and Communities project:

Carbon emission reduction

One of the standout achievements of the Sharing Cities project has been its contribution to a substantial reduction in carbon emissions. The project succeeded in eliminating an impressive 130,364 tonnes of carbon dioxide emissions annually. This remarkable reduction reflects a dedicated commitment to addressing the challenges of climate change and promoting a sustainable urban environment.

Building refurbishment

A core element of the project involved the refurbishment of 900 apartments. This initiative not only improved the living conditions of residents but also had a positive impact on energy efficiency. It played a vital role in reducing energy consumption, further aligning with the project's sustainability goals.

Smart lamppost deployment

The introduction of 2,400 new smart lampposts was another noteworthy accomplishment of the Sharing Cities project. These smart lampposts not only improved urban lighting but also represented a move towards more energy-efficient and technology-driven urban infrastructure. This innovation contributed to reducing energy consumption and enhancing the overall quality of urban lighting.

Energy savings through retrofitting

The project achieved significant energy savings, totalling 6,124,500 kilowatt-hours per year, primarily due to the retrofitting of buildings. This retrofitting not only reduced energy bills but also decreased the demand for non-renewable energy sources, fostering a more eco-friendly and economically sustainable urban future.

Energy delivery for space heating

942 kWh per year of energy were delivered for space heating, contributing to the project's energy efficiency goals and providing residents with more comfortable and sustainable heating solutions.

Digital social market usage

The Digital Social Market introduced by the project proved to be an asset, with 4,200 users actively engaging with this platform. This demonstrated a significant adoption of digital technology to foster environmentally responsible and sustainable behaviour.

In summary, the Sharing Cities project's focus on carbon emission reduction, housing refurbishment, smart lamppost deployment, energy savings through retrofitting, energy delivery for space heating, and the utilisation of digital platforms has collectively resulted in a substantial positive impact on energy efficiency and climate sustainability. These achievements underscore the project's dedication to creating more energy-efficient, sustainable, and climate-responsible urban environments, benefiting both residents and the planet.

3.2.4. Sharing Cities Investment Impact

Sharing City set the goal of triggering EUR 500 million investment in smart city solutions. As of December 2020:

- 100 opportunities were captured in the Trigger Tracker database
- EUR 1 billion 'addressable' investment were captured in the funnel
- EUR 250 million was 'secured'[8], from 24 opportunities adjusted for level of influence
- 45% of opportunities did not include investment figures (i.e., considerable upside)

Figure 3 provides a visual summary of this information [5], while Figure 4 illustrates the overall measurement capture.

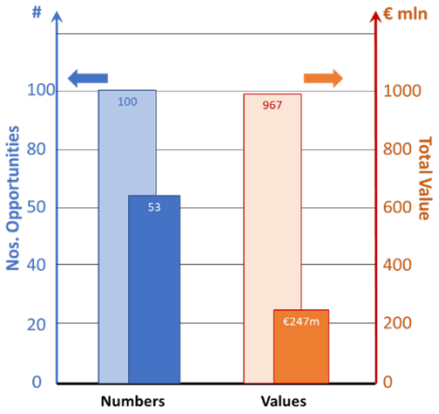

Figure 2: Towards the EUR 500 million triggered investment goal

[8] *'Secured' includes more-progressed opportunities where Sharing Cities has influenced activities*

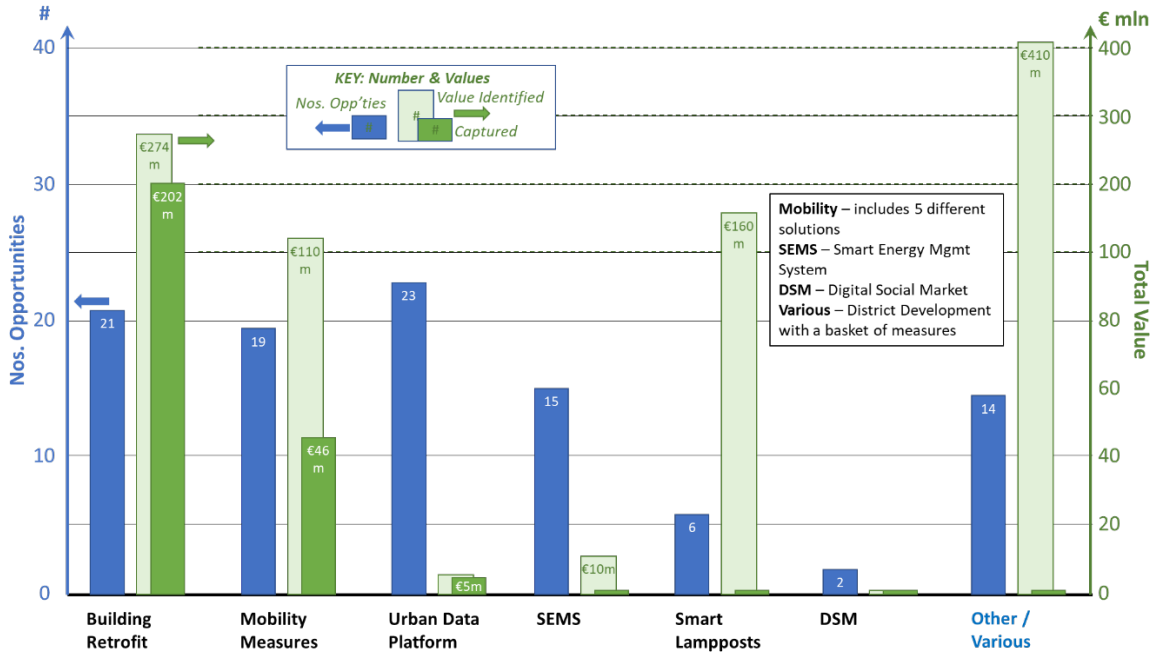

Figure 3: Measure / solution opportunities identified & valued

Insights drawn from Figures 3 and 4 include:

1. Opportunities associated with building retrofit and mobility both represented a significant number and financial value, while data platforms (both UDP and SEMS) were substantial in number, however, do not represent such significant financial investments
2. A significant investment in the scale-up of building retrofits was already been captured – notably through work in Burgas (EUR 165 million captured and contracted), and Milan (EUR 40 million)
3. The Digital Social Market (DSM) was a novel solution for which future scale-up is anticipated after more market testing. It does, however, hold significant enabling potential.
4. Smart lampposts held considerable bankable ROI, and significant potential volumes have been identified, yet this smart city 'quick win' remains challenging to implement.
5. Substantial financial potential existed in the opportunities related to district developments, notably in Warsaw (EUR 300 million Praga development) and London (a growing number of Smart Districts targeted)

Figure 5 below provides a deeper analysis based on developments within each city and their associated region/nation and EU / Rest of World developments.

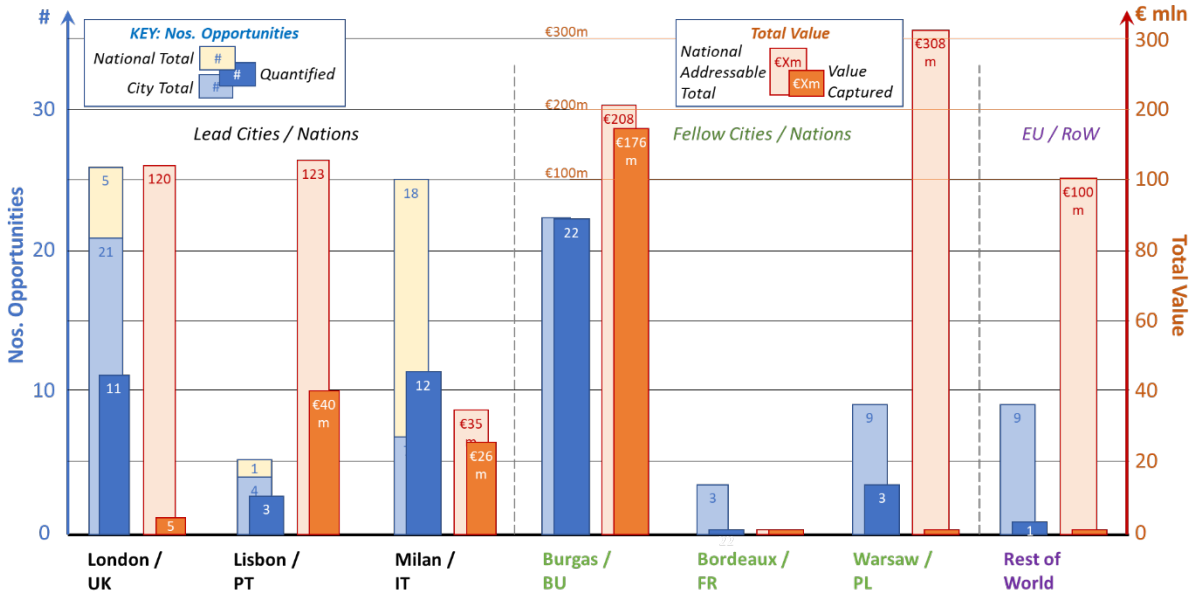

Figure 4: Opportunities and values by city/geography

There were considerable variances in the data between cities. However, a number of intriguing insights can be drawn from Figure 5:

1. Burgas stood out in many ways as a city that had taken the task of being a 'fellow city' to heart. The city team captured and quantified the highest number of opportunities. The city has also captured the largest amount of 'triggered' investment. Although the vast majority of the investment represented building retrofits, the city continues to broaden its portfolio of plans to include most all of the Sharing Cities measures.
2. Milan demonstrated clear influence over regional and national cities, notably in adopting data platforms. The city also had great success in delivering private shared housing retrofits.
3. Bordeaux had limited present traction, predominantly due to the loss of the Mayor (Alain Juppe), and then a subsequent change in political allegiance. This clearly highlights the realities of political disruption in urban decision-making and development.
4. London and Milan took significant steps to influence regional and national peer cities, and of late, additional early notions and plans are emerging from other (lead & fellow) cities.
5. A number of significant-sized opportunities were identified in non-EU geographies (Middle East, Australia, LATAM), where the social and sustainability focus on EU smart city developments is seen to be of notable interest.

The most significant message that can be drawn from the above graph is that of untapped and very significant potential.

The means by which such potential can be most productively delivered is by presenting to the market projects that instil confidence in city decision-makers and with public and private investors. That is where the concept of packaging of measures plays in strongly – capturing the functional specifications of a solution such that it can be tailored to a physical reality within the context of a target city. By addressing the social needs, technical specifications, and business model and financing options in a clear, multi-disciplinary manner and adopting a component-based approach ('Lego'), the eventual solutions will be implementable in a swifter, more reliable, and more affordable way.

Key Learnings

Achieving scale adoption in the market is advantageous and comes with both opportunities and challenges. Some of the key learning points from the experiences thus far are captured below:

- **Link to city needs and outcomes –** More often than not, programmes such as Sharing Cities are operated out of one city department, with other departments unaware of the work being carried out and the learning that accompanies. To help bridge this gap, it is vital that the outputs of funding programmes are linked to the city's needs and outcomes to make the programme relevant to key decision-makers.
- **Political impact** – where there is political will, there is a way. And where there is an absence of it, progress is slow.
- **Technical versus financial mindset** – partners in EU-funded projects tend to be more tuned to technical activities. Funding is provided by EU grants to 'get things done'. The need to focus on designing technical solutions in a manner that will attract investment and structuring business models in a way to enable this is an increasingly important facet of future work.
- **Specific deliverables versus bold goals** – two points of note: (i) naturally, the partner's primary focus is on contractually committed deliverables to INEA. These are clearly vital. However, they may not always contain an easy-to-access and digestable set of materials supporting scale-up activities. They do contain solid content. However, a deliverable structure is unlikely to align with what is required for easy access by cities; (ii) adoption of overarching programme goals is not something that individual partners naturally align with, so the need for external advisory boards, programme boards, and the like to keep a focus on strategic programme goals comes to the fore.
- **Timing matters** – not unrelated to the above, the more that focus on 'non-traditional' matters (business models, financial and strategic goals, etc.) can be brought in early, the better. Indeed, early structuring can help align and make delivery actions more efficient.
- **Regional & national scale-up** – in similar contexts (jurisdiction, language, cultures, etc. – ref 'context characteristics in packaging approach'), clear opportunities and low barriers to scaling exist. An excellent example is Milan's Data Platform influence on a dozen or so cities in nearby Italian regions. Or the work of GLA (London) chairing the group of UK SCC01 cities, which has now expanded somewhat to build the foundations to scale-up, aligned with activities of BSI to stimulate national-level coordinated city activities.

Way Forward & Recommendations

Recommendations beyond Sharing Cities:

Below are a handful of recommendations that could strengthen the collective opportunity to deliver overall joint[9] ambitions:

1) Establish cross-SCC01 Scale-Up Goals and Targets – if Sharing Cities can trigger EUR 500 million investment, others could (in theory) do similarly. They are not presently explicitly motivated to do so. However, it would seem wise to discuss and develop a joint target. This could considerably help support the Climate Neutral & Smart Cities Mission goal of 100 PEDs by 2030, given that a PED is a combination of many of the measures that are being demonstrated.
2) Apply a common pragmatic opportunity funnel and scale-up tracking system – keeping the processes 'light touch' could provide both a politically engaging ambition and not create overly burdensome administrative capture and monitoring processes.
3) Focus on Fellow cities as a leverage point for scale-up presents a more consistent portfolio of 'lighthouse' measure designs for new programmes and fellow cities. A far more fluid and productive

[9] *"joint" here includes the ambitions of the Climate-Neutral & Smart Cities Mission; EC DG staff; CINEA contract managers; individual SCC01 programmes; individual cities involved; other consortium partners; the two significant support contracts for the SCC01 collective, and Smart Cities Marketplace; and investors.*

market will emerge where there is collaboration between cities across programmes – particularly where they are in similar geographies and jurisdictions.

4) Engage the investor community properly – there is a clear and recognised gap between the various investor types and the cities market. Given that public finances are shortening supply and considerable funds are in the commercial market, there is a clear opportunity for scale adoption of solutions if the appropriate steps are taken.

3.3. mySMARTLife

Table 9: mySMARTLife project description

Project	Focus fields / Aim	Lighthouse Cities	Follower Cities
mySMARTLife (Dec 2016 – Sep 2022)	The project aimed to create an Urban Transformation Strategy to develop transition models and address the main challenges a city faces. This was done in an integrated approach based on an impact assessment, active citizen engagement and structured business approaches. Lighthouse cities were obligated to introduce large-scale interventions and to collect at least two years of data for an in-depth analysis. Activities focused on ■ "Inclusive cities" ■ "Smart economy" ■ "Smart people"	Helsinki (FL) Hamburg (DE) Nantes (FR)	Rijeka (CR) Palencia (ES) Bydogszcz (PL)

The 'My Smart Life' project aimed at fostering urban transformation and addressing the key challenges faced by the cities involved. It sought to create an Urban Transformation Strategy by developing transition models that integrated an impact assessment, active citizen engagement, and structured business approaches. In this holistic approach, both Lighthouse Cities and Follower Cities played pivotal roles.

The Lighthouse Cities Helsinki (Finland), Hamburg (Germany), and Nantes (France) were entrusted with the task of introducing large-scale interventions within their urban environments. These interventions were designed not only to bring about immediate improvements but also to collect a minimum of t'o years' worth of monitoring data, allowing for an in-depth analysis of their impact. This data-driven approach was vital in understanding the effectiveness and sustainability of the implemented solutions.

The project's activities revolved around three central focus areas: Inclusive Cities, Smart Economy, and Smart People:

Inclusive cities

Creating cities that are inclusive and accessible to all residents, irrespective of their backgrounds or abilities. This involved addressing urban development in a way that promotes equality, diversity, and social cohesion.

Smart economy

Fostering economic growth through innovation, technology, and sustainable practices. The aim was to create urban environments that support the growth of businesses and stimulate economic development while considering environmental and social factors.

Smart people

Placing residents at the centre of urban development. The focus here was on enhancing the quality of life for citizens by providing them with access to smart and innovative services, technologies, and solutions.

In addition to the Lighthouse Cities, the project involved three Follower Cities, namely Rijeka (Croatia), Palencia (Spain), and Bydgoszcz (Poland). These cities benefited from the insights, experiences, and best practices developed in the Lighthouse Cities. By replicating these strategies, they, too, played a significant role in advancing the goals of urban transformation and creating more vibrant and sustainable urban landscapes.

The "My Smart Life" project was a dynamic and forward-thinking initiative to bring forward smart urban development by addressing urban challenges through an integrated approach. It was committed to creating urban environments that are inclusive, economically vibrant, and centred around the needs and aspirations of its residents, ensuring a smarter, more sustainable, and better quality of life for all.

3.3.1. Key results

Table 10: MySmartLife key results

PROJECT	SOLUTION CLUSTER	KEY RESULTS
MySmartLife[10]	Energy	■ **49,102 m²** retrofitted in three Lighthouse Cities ■ **8,600 kWh/y** were saved in retrofitted buildings ■ Pledge to subsidize **500 housing units per year** for lower-income communities.
	Mobility	■ **4,810 tCO_2/y of CO_2 emission savings** through sustainable mobility.
	ICT	■ Three urban data platforms deployed with **significant access** ■ **Thousands of sensors** were integrated into Urban Platforms

The "My Smart Life" project has delivered significant and replicable results across various solution clusters, contributing to a more sustainable and forward-thinking urban environment. Here are the noteworthy outcomes of this innovative initiative:

Energy

Under the energy solution cluster, the project focused on the retrofitting of buildings in the three Lighthouse Cities. A total area of 49,102 square metres was retrofitted, resulting in substantial energy savings. These energy-efficient improvements led to a remarkable reduction in energy consumption, with 8,600,000 kilowatt-hours per year being saved in the retrofitted buildings. Additionally, a significant commitment was made to subsidise 500 housing units per year for lower-income communities, thereby addressing social and economic disparities while promoting sustainability.

Mobility

The project made substantial strides in mobility by significantly reducing carbon emissions. Sustainable mobility solutions resulted in the reduction of 4,810 tonnes of carbon dioxide emissions per year. This achievement aligns with the project's commitment to environmentally responsible and eco-friendly urban transportation options.

[10] Data source:
https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5f3e01dd3&appId=PPGMS
Smart People - Smart Economy - Smart Cities (mysmartlife.eu)

ICT

In the domain of Information and Communication Technology (ICT), the project deployed three urban data platforms with a wide-reaching impact. These platforms played a pivotal role in collecting, managing, and disseminating valuable urban data. To further enhance data collection, thousands of sensors were integrated into these Urban Platforms, providing a wealth of information for informed decision-making and more effective urban management.

In summary, the "My Smart Life" project's achievements across energy, mobility, and ICT solution clusters have laid the foundation for a more sustainable and technologically advanced urban environment. By focusing on energy-efficient building retrofitting, reducing carbon emissions through sustainable mobility solutions, and harnessing the power of data through urban data platforms, the project has significantly improved the quality of life in the participating cities. These outcomes reflect the commitment of the "My Smart Life" project to fostering environmentally responsible and technologically advanced urban living while also addressing social and economic disparities.

3.3.2. Project Highlights

Hamburg: High-Performance New Constructions "Am Schleusengraben"

The new building intervention was part of the mySMARTLife project in Hamburg, involving the construction of 79 energy-efficient buildings in the Schleusengraben area. Specifically, the focus was on the development area "Am Schilfpark," consisting of 9 buildings with 370 housing units. These structures were considered to meet uniform energy-efficient building standards and were integrated into a district heating system partially powered by renewable hydrogen. The district heating system comprised two combined heat and power units and two gas boilers. The district heating system was tested by the University of Applied Sciences Hamburg, the energy utility company Enercity AG, and the gas grid operator Gasnetz Hamburg GmbH with a hydrogen content of up to 30% in the fuel gas.

Impacts

- Installation of a 460 metres long district heating network in the underground
- Construction of two Combined Heat and Power plant (CHPs) with a capacity of 50kWel/100kWth each
- Construction of two gas boilers with a capacity of 500kWth each
- Attaining a share of hydrogen injection in the DH system of 2.6% over a 12-month period
- Reduction in annual energy consumption of 35.9%
- Reduction in total primary energy consumption of 6.5%
- Reduction in greenhouse gas emissions of 8%

Sources

- mySMARTLife, 'Interv–ntions - mySMARTLife'. Accessed: Oct. 16, 2023. [Online]. Available: https://mysmartlife.eu/interventions/
- mySMARTLife Consortium Partners, 'D5.5 Evaluation. Impact assessment at Smart City Project level and Smart City level', MySmartLife, 2022. [Online]. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5f3e01dd3&appId=PPGMS

Nantes: The E-Busway

Nantes' main source of greenhouse gas emissions (49%) is transportation. Of this, 88% are generated by cars, 11% by public transportation. Therefore, Nantes introduced 22 fully electric e-buses, each 24 metres long and capable of accommodating 150 passengers for the public transportation system. These buses are 100% bi-articulated buses with 150 seats. This offers an increase in passengers of 35%. Charging happens rapidly while passengers get on and off the bus through bottle-feeding. This initiative aimed to improve onboard comfort, noise reduction, space availability, and onboard services, benefiting passengers, inhabitants, and pedestrians along the route. The social evaluation showed that the respondents perceived the transition to electric buses positively, with a notable impact on travel conditions and satisfaction. The intervention was generally well-received, highlighting the potential for electric buses to improve public transportation and garnering social acceptance from end-users.

Impacts

- Reduction of energy consumption by 30%
- E-Busway saved 3,000 tonnes of CO_2 per year
- Charging that does not impact travel time

Sources

- mySMARTLife, 'Interventions – mySMARTLife'. Accessed: Oct. 16, 2023. [Online]. Available: https://mysmartlife.eu/interventions/

  MySMARTLIfe Consortium Partners, 'D5.5 Evaluation. Impact assessment at Smart City Project level and Smart City level', MySmartLife, 2022. [Online]. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5f3e01dd3&appId=PPGMS

Helsinki: High-Performance Residential Buildings in Kalasatama

Kalasatama is a modern residential area in Helsinki, featuring 67 buildings and approximately 4,500 flats. The development mandate incorporates smart technologies in all buildings, including smart home solutions with smart meters. The mySMARTLife project focused on information gathering and collaborative development of a smart energy district in partnership with the Smart Kalasatama initiative.

Under the mySMARTLife project, these buildings have integrated smart home solutions, renewable energy sources (RES), waste heat recovery, and smart meters in all flats. The buildings are connected to a district heating network for thermal energy, utilising it for heating and domestic hot water. Some buildings also have privately owned photovoltaic panels totalling 28.72 kWp capacity as of September 12, 2022.

In the Kalasatama area, the district heating system covers all the thermal needs of the buildings, while solar panels contribute to the electricity needs. During the summer, excess solar and waste energies are stored and integrated into Helsinki's district heating system.

The buildings utilise excess heat and natural light during the winter through solar radiation, benefiting energy efficiency and comfort. The residents generally perceived the intervention positively, appreciating aspects like general comfort, lighting in common areas, and indoor air quality.

Impacts

- Higher energy consumption than expected: total energy consumption for buildings increased by 8% in 2020 and 11% in 2021 compared to 2015. (COVID-19 pandemic significantly impacted energy consumption patterns due to increased presence at home)
- Total greenhouse gas emissions decreased by 8% in 2020 and remained stable in 2021.

Source

- mySMARTLIfe Consortium Partners, 'D5.5 Evaluation. Impact assessment at Smart City Project level and Smart City level', MySmartLife, 2022. [Online]. Available:

https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5f3e01dd3&appId=PPGMS

3.3.3. Main impacts

The "My Smart Life" project has delivered significant and commendable outcomes with a clear focus on energy efficiency and climate impact, contributing to a greener and more sustainable urban environment. Here are the key achievements of this forward-thinking initiative:

Energy efficiency through retrofitting

One of the project's central achievements was the retrofitting of an extensive 49,102 square metres of floor area. This initiative significantly improved the energy efficiency of buildings, leading to remarkable energy savings. The project was successful in reducing energy consumption by a substantial 8,600 kilowatt-hours per year. This not only translates into lower energy bills but also signifies a reduced reliance on non-renewable energy sources, aligning perfectly with the project's sustainability goals.

Reduction of carbon emissions through mobility measures

The project's commitment to sustainable mobility solutions has led to a noteworthy reduction in carbon emissions. It succeeded in eliminating an impressive 4,810 tonnes of carbon dioxide emissions annually. This achievement reflects the project's dedication to addressing the challenges of climate change and promoting eco-friendly urban transportation options.

In summary, the "My Smart Life" project's significant achievements in energy efficiency and carbon emissions reduction underscore its commitment to creating a more sustainable and environmentally responsible urban environment. By focusing on energy-efficient building retrofitting and sustainable mobility measures, the project has made substantial strides in enhancing the quality of life for residents while contributing to a greener and climate-resilient urban future. These outcomes exemplify the project's dedication to fostering innovative and sustainable urban living.

3.4. RUGGEDISED

Table 11: RUGGEDISED project description

Project	Focus fields / Aim	Lighthouse Cities	Follower Cities
RUGGEDISED (Nov 2016 - Oct 2022)	Urban spaces with secure, affordable, and clean energy, smart electro-mobility, smart tools and services were created under the RUGGEDISED name. The strategy resulted in clean, safe, attractive, inclusive, and affordable environments, a minimized environmental impact and a stimulating environment for sustainable economic development. Finding solutions was not the main concern of this project, but rather developing business models that can enable large-scale deployment and replication of solutions. The main challenges to overcome in the lighthouse cities were: ■ Managing peak load variation in thermal and electrical energy supply and demand ■ Developing appropriate coordination and business models for energy exchange ■ Developing smart city data platforms	Rotterdam (NL) Glasgow (UK) Umeå (SE)	Gdansk (PL) Brno (CZ) Parma (IT)

The "RUGGEDISED" project set out to transform urban spaces into secure, affordable, and clean energy hubs, incorporating smart electro-mobility as well as a range of smart tools and services under the RUGGEDISED banner. The overarching strategy was to create urban environments that are clean, safe, attractive, inclusive, and affordable, all while minimising their environmental impact. Simultaneously, the project aimed to foster a stimulating environment for sustainable economic development, reflecting its holistic approach to urban transformation.

One distinctive aspect of the RUGGEDISED project was its emphasis on developing not just solutions but viable business models that could facilitate large-scale deployment and replication of these solutions. This forward-thinking approach aligned with the project's ambition to extend its impact across various urban environments.

The primary challenges that the project aimed to overcome in the lighthouse cities, which included Rotterdam (Netherlands), Glasgow (United Kingdom), and Umeå (Sweden), were multifaceted. These challenges included effectively managing peak load variations in thermal and electrical energy supply and demand, developing appropriate coordination and business models for energy exchange, and creating Smart City Data Platforms.

In summary, the "RUGGEDISED" project was a visionary endeavour that sought to create urban spaces that are not only energy-efficient but also economically sustainable. By embracing secure, affordable, and clean energy and incorporating smart mobility solutions, the project's aim was to foster innovative, inclusive, and environmentally responsible urban environments. The focus on developing business models and addressing key challenges underscored the project's commitment to scalable and replicable solutions, thereby setting the stage for more resilient and sustainable urban living.

3.4.1. Key results

Table 12: RUGGEDISED key results

PROJECT	SOLUTION CLUSTER	KEY RESULTS
RUGGEDISED	Refurbishment	▪ **90.5t/y of CO_2** reduction achieved by building efficiency measures ▪ **2,480 MWh/y** of energy savings by building efficiency measures ▪ **43,854m ²** of newly built floor area (tertiary) ▪ **58,244m²** of refurbished floor area
	Electric Grid	▪ **325,340 kWh/y** of thermal energy generated ▪ **2,622,695 kWh/y** of electricity generated by RES (Renewable Energy Sources) ▪ **640 kWh** of electricity storage ▪ **3 MWh** installed RES capacity electricity
	Mobility	▪ **2,218 tCO2/y** savings ▪ **367 kgNOx/y** saved ▪ **55 Vehicles** with alternative energy carriers ▪ **2 new e-hubs** ▪ **5,210 MWh/y** of energy savings by mobility measures

The RUGEDISED project has yielded impressive and transformative outcomes across various key solution clusters, significantly enhancing urban sustainability and energy efficiency. Here are the key achievements of this forward-thinking initiative:

Refurbishment

Under the refurbishment solution cluster, the project focused on building efficiency measures, resulting in substantial energy and environmental benefits. The project achieved a significant annual reduction of 90.5 tonnes of CO_2 emissions through building efficiency measures. This represents a commendable step towards reducing the environmental impact of urban buildings. Additionally, the project achieved energy savings of 2,480 MWh per year through these efficiency measures, further promoting energy conservation and sustainability.

In terms of infrastructure, the project added 43,854 square metres of newly built floor area (tertiary) and refurbished an additional 58,244 square metres of floor area. This expansion and renovation demonstrate a commitment to accommodating urban growth while ensuring energy-efficient and sustainable buildings.

Electric grid

The project's electric grid solutions demonstrated an impressive contribution to sustainable energy generation. It generated 325,340 kWh of thermal energy annually, offering clean and efficient heating solutions. Moreover, the project harnessed renewable energy sources to generate a substantial 2,622,695 kWh of electricity per year, significantly reducing the reliance on non-renewable energy sources.

Electricity storage was also integrated into the grid, with 640 kWh of electricity storage capacity, further optimising energy management. In addition, the project installed 3 megawatt-hours (MWh) of RES capacity for electricity generation. These efforts reflect the project's commitment to clean, efficient, and renewable energy solutions.

Mobility

The project's mobility solutions led to substantial reductions in carbon emissions and improved urban transportation. It achieved impressive annual savings of 2,218 tonnes of CO_2 emissions and 367 kilogrammes of nitrogen oxides (NOx). This signifies a significant reduction in environmental pollutants and greenhouse gases, contributing to cleaner and healthier urban air.

The project also introduced 55 vehicles with alternative energy carriers, further promoting sustainable transportation options. Additionally, two new E-Hubs were established, enhancing the availability and accessibility of electric mobility solutions. These efforts resulted in energy savings of 5,210 MWh per year through mobility measures, emphasising the project's dedication to energy efficiency in urban transportation.

In summary, the RUGEDISED 'project's achievements in building efficiency, electric grid, and mobility solutions have made a significant impact on urban sustainability and energy efficiency. These outcomes underscore the project's commitment to creating environmentally responsible, energy-efficient, and technologically advanced urban environments. The focus on energy savings, emissions reductions, and renewable energy sources reflects the project's dedication to fostering innovative and sustainable urban living. The RUGGEDISED project has made remarkable strides in promoting energy efficiency and reducing its carbon footprint, fostering a more sustainable and environmentally responsible urban environment. Here are the key accomplishments of this forward-thinking initiative.

3.4.2. Project Highlights

Rotterdam: Smart Waste Management

In Rotterdam's Heart of South, a system of around 6,500 underground waste bins has been innovatively improved. The RUGGEDISED partners have installed sensors in textile, paper, and glass waste containers. These sensors, referred to as "filling degree metres", constantly assess the fill level of the bins every hour. Using this data, an automated system calculates the most fortune moment waste collection, optimising the routes for collection drivers through dynamic route planning. The drivers are equipped with tables or navigation systems, guiding them to the most efficient routes for waste collection. The time of collection is when the containers are filled about 75% of their capacity. A clear definition of conditions for collaboration between city and private operators is a key factor for a successful implementation. This included a clear definition of the data standards to share the information and conditions of how the data was delivered.

Impact

- Energy savings of 1,442 MWh in 2020-2021
- Carbon savings of 565 tCO_2 in 2020-2021

Source

- G. Etminan et al., 'RUGGEDISED D5.5 Assessment of lighthouse projects', Austrian Institute of Technology, 2022. [Online]. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5f721b107&appId=PPGMS

Umeå: Intelligent Building Control

Within the RUGGEDISED project, a smart control system has been installed in buildings in the University area in Umeå. In collaboration with Akademiska Hus AB 130 offices are equipped with a smart control system. This equipment controlled the air flow, room climate, and lighting based on occupancy. The solution was installed in the Physiology House, a lab building with 24-hour ventilation. Additionally, the hospital in

Umeå also adopted a similar smart control system for its office areas, aiming to reduce heating and electricity demand while improving system control.

The solution significantly reduced heating and electricity demand, leading to substantial primary energy savings and a notable reduction in CO_2 emissions, aligning with sustainability goals. The project highlighted the need for profitability analysis in extensive renovations and stressed the importance of aligning system implementation with cost-effectiveness. The insights gained will guide future projects, emphasising careful consideration of implementation costs and technical training requirements. The solution is deemed replicable in new constructions in Sweden, where strict ventilation requirements align with the system's effectiveness. However, adaptation for other European cities may necessitate considering different requirements and potential additional costs.

Impact

- 34,880 m² of refurbished floor area
- Reduction of 90.46 tCO_2 annually

Source

- G. Etminan et al., 'RUGGEDISED D5.5 Assessment of lighthouse projects', Austrian Institute of Technology, 2022. [Online]. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5f721b107&appId=PPGMS

Glasgow: Integration of Near-site RES with an e-charging Hub

The innovative solution involves installing a 200kW solar canopy on the roof of a multi-story car park, utilising the power generated by the photovoltaic array to support the building's electrical load, charge electric vehicles (EVs), or store energy for later use. The goal is to maximise the use of locally generated renewable energy, minimising reliance on the electrical grid and reducing associated CO_2 emissions from the car park and EV charging.

The solution's business model explored various revenue streams, highlighting the need for diverse income sources to make such systems financially viable. The innovative combination of technologies challenged traditional mindsets and operations, fostering new approaches for car park owners and city authorities. The assessment underlines the potential for replicating this solution, especially if battery prices continue to decrease, making the business model more feasible. Replication prospects are influenced by solar PV capacity, grid conditions, and economic factors in different cities.

Impact

- Reduction in carbon emissions of 11 tCO_2 per year
- Savings of 118 MWh of primary energy annually
- Reduction of peak energy demand by 34%.

Source

- G. Etminan et al., 'RUGGEDISED D5.5 Assessment of lighthouse projects', Austrian Institute of Technology, 2022. [Online]. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5f721b107&appId=PPGMS

3.4.3. Main Impacts

One of the standouts impacts of the RUGEDISED project has been the substantial reduction in carbon emissions. The project succeeded in eliminating an impressive 9,461 tonnes of CO_2 emissions annually. This remarkable reduction reflects the project's dedication to addressing the challenges of climate change and promoting cleaner urban living.

Charging infrastructure expansion

The project introduced 21 new charging stations, significantly enhancing the infrastructure for electric vehicles. This expansion not only facilitates the adoption of electric mobility but also contributes to reducing greenhouse gas emissions and air pollutants, fostering cleaner and healthier urban transportation.

Refurbished floor area

The project focused on refurbishing and renewing urban buildings, resulting in the refurbishment of an extensive 58,244 square metres of floor area. This initiative not only improved the quality and efficiency of these buildings but also contributed to energy savings and sustainability. It reflects the project's commitment to modernising urban infrastructure in an environmentally responsible manner.

Renewable energy generation

The RUGGEDISED project harnessed renewable energy sources to generate a substantial 2,622,695 kWh of electricity annually. This achievement significantly reduced the reliance on non-renewable energy sources, contributing to a cleaner and more sustainable energy supply. It reflects the project's commitment to clean and eco-friendly power generation.

Job creation and economic development

The project's impact extended beyond the environmental sphere, contributing to the economy and livelihoods. In Umea, at least 430 jobs were created, emphasising the role of such initiatives in stimulating sustainable economic development and improving the quality of life for urban residents.

In summary, the RUGEDISED project's achievements in carbon emission reduction, infrastructure expansion, renewable energy generation, building refurbishment, and job creation underscore its commitment to fostering cleaner, more sustainable, and economically vibrant urban environments. These outcomes exemplify the project's dedication to creating innovative and environmentally responsible urban living while also driving economic growth and employment opportunities.

4. Summary of the Main Achievements and Impacts

This report covers four projects and 23 cities (12 Lighthouse and 11 Follower Cities). The focus of these projects was on societal change, supporting smart city communities, and ensuring secure, clean and efficient energy to reduce the cities' carbon footprint. This chapter summarises the main achievements and impacts of these four projects.

4.1. Key results

In total, 55 solutions (see Figure 6) were reported by the four projects in the Self-Reporting Tool (SRT) of the Smart Cities and Communities Marketplace:

- 30 solutions had a focus on energy. The main topics were refurbishing old buildings, constructing new buildings, and improving energy systems with integrated energy systems, e.g., waste heat, photovoltaic powerplants, electrical storage, and sorption-chillers (see Figure 7).
- 14 solutions used information and communication technology (ICT). In the ICT cluster, the following solutions were developed: applications to monitor energy consumption and help users change their behaviour; apps for sustainable mobility; parking management systems; virtual games on energy usage, traffic and sound sensors; data platforms; and smart lighting systems.
- 11 solutions focused on the topic of mobility. Of these, more than half (63%) focused on the implementation of e-mobility solutions, as car and bike-sharing systems and other projects focused on charging infrastructure for electric vehicles.

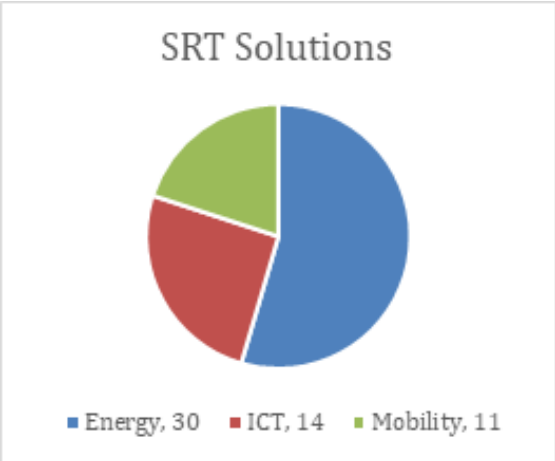

Figure 5: Solutions per cluster (SRT)

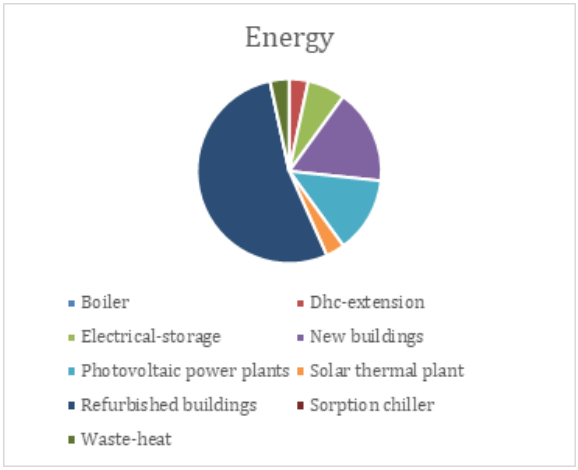

Figure 6: Energy solutions (SRT)

On the project and city level, the SRT results can be seen in the following two graphs (Figure 8). The most important thing to read here is that SmartEnCity has not entered a single solution into the SRT. This shows that even the numbers that can be aggregated from the SRT are not viable because they lack validity.

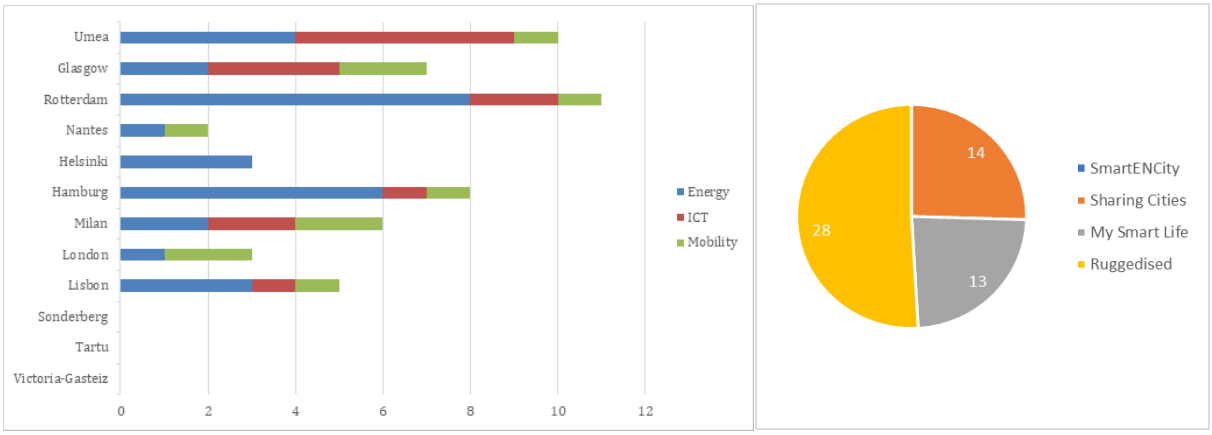

Figure 7: Solutions per cluster and project (Source: SRT)

Due to the lack of reported data in the SRT, additional sources, such as the project websites public deliverables, have been leveraged to identify the number of implemented solutions in the projects. Figure 9 shows the comparison of reported solutions in the SRT and the project websites and public deliverables.

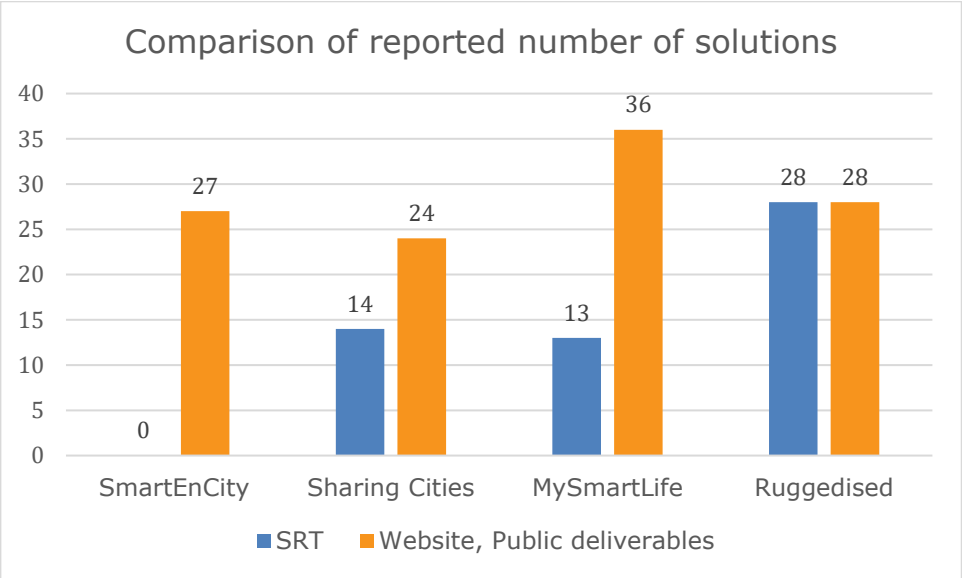

Figure 8: Number of solutions per project (Sources: SRT project websites, project deliverables)

4.2. Main impacts

The total number of impacts at the project level is listed at Table 13. KPIs were selected based on the information provided in the final reports of the individual projects. Many of the KPIs or their measurement formats at the project level are not compatible with each other. Therefore, the new projects will be individually summarised, and then a table with all projects should summarise the assessment.

SmartEnCity

- Retrofitting of 1,847 dwellings and 124,506 m² of floor area.
- Benefits for at least 29,300 inhabitants
- Energy savings of approximately 27,000 MWh/y
- CO_2 reductions of 20,622 tonnes/y

Sharing Cities

- CO_2 reduction of 130,364 tonnes/y
- Refurbishment of 900 dwellings
- 2,400 new smart lampposts
- Energy savings of 6,125 MWh/y due to retrofitting
- 4,200 users of Digital Social Market

MySmartLife

- Retrofitting of 49,102 m² of floor area
- Energy savings of 8,600 kWh/y due to retrofitting
- CO_2 reductions of 4,810 tCO_2/y due to mobility measures

RUGGEDISED

- CO_2 reductions of 9,461 tCO_2/y
- 21 new charging stations
- Refurbishment of 58,244m² of floor area
- 2,623 MWh/y of renewable energy generated
- At least 430 jobs created (numbers only exist for Umea)

The table below shows the numbers in more detail, yet not all KPIs were calculated for every project.

Table 13 Impact assessment of the four projects

KPIs	SmartEnCity	Sharing Cities	mySMARTLife	RUGGEDISED	Sum	Unit
Total carbon savings	20,622		9,219	9,462	**39,302**	tCO_2/y
Number of charging stations		244		21	**265**	#
Refurbished floor area		6,766	49,102	58,244	**114,112**	m^2
Smart lampposts		2,400			**2,400**	#
Renewable energy production				2,623	**2,623**	MWh/y
Primary energy savings	27,000			26,834	**53,834**	MWh/y
Due to retrofitting		6,124.5	8.6	2.5	**6,136**	MWh/y
Additional KPIs						
ICT users		DSM users: 4,200			**4,200**	#
Number of people involved	293,000				**293,000**	#
Jobs created				430	**430**	#
Grant amount	28,000,000	28,000,516	18,656,102	17,692,858	**92,349,476**	EUR

5. Barriers for a Successful Implementation

Several of the projects summarised their experiences within the projects in their deliverables. In this chapter, we will emphasise the barriers cities and projects faced. These barriers are analysed by the projects themselves and only summarised here. Challenges and barriers across the four projects have been collected based on monitoring, recommendations, and assessment reports.

These barriers can be summarised in five clusters:

- **Financial and economic barriers** concerning investments and costs of solutions. The second cluster is the **technical barriers** related to the implemented technologies;
- **Social and cultural barriers** faced during projects, such as acceptance;
- **Political and regulatory challenges.**

The common general challenges in the action fields of Urban Retrofitting, ICT, Mobility and Energy have been identified across the four projects. This summary gives an overview of what challenges are still relevant and need to be tackled.

The following summary represents only an excerpt of the **common main challenges** that the eight Lighthouse cities face.

5.1. Financial and economic barriers

District heating sizing and business models

- District heating has been seen as a new technology in many areas and cities of the projects, which has led to uncertainties in sizing and determining suitable business models. In addition to that, the ownership and exploitation decisions for the district heating system are complex and can be delayed due to the need for political decisions regarding public sector involvement. Looking at the economic viability of the implementation, a minimum number of buildings need to be connected to the district heating system.

Barriers in tax systems and support schemes

- Tax systems and support schemes may present obstacles, hindering the effective integration and promotion of renewable energy technologies. For example, renewable energy sources (RES) technologies, despite advancing, continue to face challenges in competing with traditional power plants in today's market [6]. Moreover, these innovative technologies are not consistently acknowledged for their environmental benefits and flexibility.
- Lack of investments/ high investment costs: Several stakeholders faced tight budgetary constraints. Public authorities lack public investment. Technological solutions face barriers due to lack of investment in innovation, and unexpected costs are not accounted for in advance.
- Cost and funding challenges have been experienced, in particular regarding the retrofitting of buildings. Retrofitting buildings is expensive, and securing funding, especially for private buildings, can be challenging, limiting the pace of adoption and implementation [7].
- Investing in smart solutions, especially innovative ones, is a significant financial risk, while payback periods tend to be long. This can become a major burden for solutions that require private investments, such as retrofitting [6].

- Also, when looking at the financial feasibility of smart thermal Grids, the implementation may pose challenges due to the high costs associated with developing and upgrading the necessary infrastructure. This includes the installation of advanced monitoring and control systems, adding to the overall expenses [8].
- Financial risks in ICT investments arise from factors like untested products, fluctuating costs, and uncertainty regarding market performance.

Cost-effectiveness

- There is sometimes a discrepancy between ambitious building energy concepts and the cost-effectiveness of projects. There is a unilateral focus on energy consumption even if there is a surplus, (for example, the Danish Building Code requires new buildings to be almost zero-energy buildings). Yet sometimes there is a surplus of heat from, for example industries, and this heat is wasted instead of used [6].
- The economic viability of retrofit measures is impacted by the cost of electricity compared to gas, which can affect the affordability and attractiveness of retrofitting buildings [6].

Cost-effectiveness in ICT solutions

- The perception of cost-effectiveness in ICT solutions is influenced by factors like technology readiness, market acceptance, and the comprehensive assessment of benefits, including environmental advantages. Subsidies for technology development often yield limited results. Achieving competitiveness may require substantial scaling efforts. Cost-effectiveness evaluations based on current energy prices may fail to consider benefits like improved air quality from initiatives such as electric vehicles [6].

5.2. Social and cultural barriers

Importance of trainings and resident engagement

- Acceptance of change and technological development by citizens is often a barrier [6]. RUGGEDISED has been successful in raising awareness about energy-neutral building practices among workers and business owners, contributing to the dissemination of knowledge and understanding [8]. That means, e.g., implementing energy-neutral building technologies highlights the necessity for personnel training and human capital development. Therefore, education and training programmes are essential to equip individuals with the skills needed for successful implementation.
- A socio-economic divide was revealed in citizen participation and co-creation processes. This means that not all citizens have the same opportunities or interest in participating in participatory and co-creative processes due to their financial or socio-economic situation or due to family or professional circumstances.

Information asymmetry

- Low energy awareness creates a barrier to understanding and accepting concepts like district heating and biomass boiler rooms [6].
- The lack of information or uneven distribution of information among decision-makers and practitioners can hinder the adoption of energy-efficient technologies.
- The previously mentioned challenges also reinforce the challenge of limited knowledge about available technologies and their economic and environmental benefits, which also hinder the replication of the solutions.
- Improving energy efficiency often requires education and training of occupants like tenants, workers, or business owners about the management of the system. It also raises awareness of smart solutions

[8]. Thus, the implementation of energy-neutral building technologies has underscored the need for personnel training, emphasising the importance of human capital development. The projects also show that behavioural change and resident engagement play a crucial role in optimising energy savings, particularly in retrofitted buildings. In the implementation of mobility solutions, success factors depend very much on user behaviour, accessibility, and adoption.

Collaboration knowledge exchange and cooperation

- Collaborative knowledge exchange and cooperation with knowledge institutes and universities are crucial to overcome complex technical barriers and can contribute to the successful implementation of solutions.

Divergence between actors

- Coordination among different actors from various sectors or functions is often necessary for implementing energy-efficient measures, leading to conflicts of interest, such as the landlord-tenant problem or cross-departure barriers [6].

5.3. Technical barriers

Complexity in the implementation of smart grids

- The implementation of smart thermal grid solutions may pose challenges due to technical complexities. It requires careful consideration of the existing urban infrastructure and seamless integration into the environment to prevent any disruptions [9].

Integration of solar-powered EV charging stations

- In general, finding storage solutions necessitates thoroughly evaluating various options to determine the most effective and efficient one for integration. So, the integration of a solar-powered electric vehicle (EV) charging station also involves structural studies to ensure the building can support the added load and address concerns about potential disruptions to the electricity network [8].

Lack of professionals

- The lack of specialised professionals in ICT solutions poses a significant challenge to the successful implementation of smart city technologies. This shortage can adversely affect the quality of implementation and hinder efficient entry into the market [6].

Data availability and accuracy

- Technical tools and simulations are essential for evaluating the impact of retrofit actions on smart city initiatives. However, the availability and accuracy of data can present challenges, potentially affecting the precision and reliability of assessments [7].

Interoperability of technologies

- Smart grid solutions encompass a range of diverse technologies and systems. Ensuring seamless interoperability among different components and devices is a critical challenge to tackle. Ensuring seamless integration and harmonisation of the technologies is crucial for the successful deployment and optimal functioning of the smart solutions [8].

5.4. Political barriers

Lack of clear objectives and strategies

- Political frameworks and municipal strategies often lack clear and actionable objectives, creating uncertainty and hindering effective planning and deployment of smart solutions.

Unclear legal conditions and varied governance structures

- Due to the innovative nature of some smart city solutions, the legal conditions for their deployment are often unclear. There are different governance structures in different cities, making replication more complex [10].
- The influence of political decisions can also impact regulations and public-private partnership arrangements for energy solutions and hinder project execution. In one project, it was shown that political leadership is very important, and can promote and drive energy efficiency initiatives, and also raise awareness, in particularly in city-owned buildings.[8]

Limited understanding and involvement of decision makers

- Decision-makers often have a limited understanding of smart city technology, which can slow down the decision-making process and thus decrease the cost-efficiency of the deployment. By not including the operational staff, decisions continuously go back and forth between the political and operational levels. This highlights the need for training and capacity building among relevant stakeholders.

Barriers to private sector involvement

- There are still significant barriers to private sector involvement in smart city projects, although this could be the solution to financial constraints [10].
- Challenges in urban retrofitting are primarily rooted in institutional failures and political considerations. Some projects reported a lack of **political will** for consistent **long-term strategies**. Decision-makers tended to plan short-term until the next election. [11]

Institutional failures and short-time planning

- Also, there is a lack of direct benefits for implementers of climate actions. Fragmented responsibilities and departments hinder the deployment of integrated solutions. Often, new concepts require political decisions. However, delays are caused by volatility in political support and urge the need of consistent policies and regulations for effective long-term planning and implementation.
- The absence of direct benefits for implementers in sustainable actions is seen as a barrier to effective deployment. Fragmented responsibilities and departments further hinder the integration of solutions, requiring consistent policies and regulations for long-term planning and implementation.

5.5. Regulatory barriers

Insufficient adaptation to technological complexity

- Regulatory gaps and barriers refer to existing regulations that may not adequately address the complexity and innovations associated with the implementation of smart solutions. For instance, in implementing urban retrofits, some SCC projects faced challenges due to environmental legislation and civic protests. For example, limitations have been experienced in installing RES-energy supply in historical city areas due to conversational interests. [9]
- Environmental legislation was restricting the potential for sites for large-scale RES plants (e.g., wind farms, solar power plants, etc.) in open land. In this case, also civic protests happened against the establishment of RES-plant due to concerns about the impact on the environment and local community. [6]

Regulatory challenges in urban retrofits

- Inconsistent regulations and standards for building retrofits cause uncertainties for project planners and stakeholders.
- Ownership structures and property laws strongly influence the implementation of building refurbishments and district heating integration. In Spain but also in other countries, it is very common that the prevalent ownership structure, mainly family-owned apartments, and property laws in Spain empower individual apartment owners, necessitating consensus within the community of owners for major refurbishment projects or connecting to district heating [6]. This can lead to delays and difficulties in decision-making for energy solutions.
- In some areas, receiving mortgage loans for energy renovations in the real estate market is less attractive, potentially due to unfavourable financial terms or limited incentives, hindering the widespread adoption of energy-efficient upgrades in buildings.

Directive limitations and lack of clear definitions

- The SmartEnCity project identified certain stipulations of the Energy Performance of Buildings Directive and of the Clean Vehicle Directive as barriers for upscaling and replicating smart city solutions. [6]

The Energy Performance of Buildings Directive (2010/31/EC)

- This directive lacks a long-term binding target for existing buildings that could further incentivize renovation of the building mass.
- This directive has a unilateral focus on the energy consumption of single buildings instead of offering a more holistic approach. Instead of focusing on single buildings, the entire value chain should be looked at, covering efficient technologies, district heating, smart metering, and billing. Both EU and national legislation primarily concentrate on the energy consumption of individual buildings, promoting investments to meet specific standards.
- However, this focus may overlook opportunities for utilising surplus energy available in the area or producing energy more cost-effectively through larger shared renewable energy systems (RES-plants).

The Clean Vehicle Directive (2009/33/EC)

- According to SmartEnCity a clear definition of clean vehicles, including minimum requirements on the environmental impact, is lacking. This also refers to the definition of sustainable alternative fuels, with indicating minimum requirements, e.g., reduce overall CO2 emissions. The evaluation proposes a well-to-wheels accountability to include the entire environmental impact produced. Additionally, some parameters have a bias towards diesel vehicles, which is not advisable for air quality.

Regulations and incentives for DSM apps and demand-side response

- Well-defined regulations and incentives related to demand-side management (DSM) apps and demand-side response programs [12] are needed to encourage effective energy management and response strategies, ensuring optimal energy use and efficiency at the community and building levels.

6. Enabling Factors for a Successful Implementation

The following enabling factors for a successful implementation were identified while analysing the four Smart Cities and Communities (SCC) projects for this report:

- **Community engagement is vital:** Involving communities and citizens in sustainability initiatives proves and fosters a project's success and can stimulate a shift towards sustainable behaviours. Across all projects, community and citizen engagement is still seen as a key factor in increasing the successful implementation and social acceptance of smart city solutions. That citizen engagement and communication with all stakeholders need to be part of the process is a well-known fact. It is crucial to involve citizens actively and keep them engaged throughout the project's duration. Another key factor is the proper and clear dissemination of information regarding the benefits and impacts of smart solutions to gain public acceptance and foster sustainable behaviour.

  Yet, several projects had issues with the effectiveness of citizen engagement. Therefore, there is a need for very clear guidance for citizen engagement and communication while offering flexibility and adaptability to the type of solution and local context. Tailoring communication strategies, approaches, and solutions to suit the specific and local context is essential. Also, considering the needs of the different communities can increase implementation and acceptance. Whether in retrofitting of buildings, mobility solutions, ICT solutions, understanding user behaviour and usage patterns, either about energy consumption or transportation choices, provides valuable insights that help tailor the design and implementation of smart solutions.

- **Building capacity to close the skill gaps:** Gaps in expertise and skills were a problem in several projects and solutions. Therefore, cities need to ensure skills and expertise are there beforehand and hire an appropriately skilled workforce. (e.g., experts in building technology to avoid problems with the energy performance of buildings in the operational phase). Developing knowledge and increasing capacity is a key step to quality implementation. In addition, quality can be improved by working together across departments. It is essential to ensure that the expertise is at a higher level and that the operational workforce is skilled in modern technology. Additionally, it is important to recognise that local knowledge by citizens is also required for projects, and communities can be considered local experts. Examples for mitigating this are to develop an asset register for specific skills, so if a city wants to replicate a project, they know where to find appropriate skills. Lecce, for example, has had the experience of creating a steering committee to offer expertise collected for the replication process to be very effective [13]. The committee engaged with network cities in the replication process and supported national coordinators with knowledge of Smart Cities topics.

- **Design for replicability and scalability:** Projects designed with replicability and scalability in mind can be effectively replicated across diverse cities, accounting for unique local requirements and contexts. For instance, establishing a steering committee, as mentioned before, to aim for supporting in replication from the beginning of the project can overcome the barriers of having a lack of expertise or funding at a later stage. Across the projects, knowledge and experience sharing between Lighthouse and Fellow Cities can be ensured by involving Fellow Cities from the beginning of the project in the process.

- **Find a solution for cross-departmental collaboration:** Issues are often dealt with in different municipal departments. This can cause a discrepancy in goal setting and strategy planning [8]. Therefore, there is a need for better collaboration with all stakeholders by introducing a designated person to take care of this task or creating a committee. This divergence of interests is also seen in private vs. public interests and needs to be covered in a similar way, taking all interests into consideration. Working in cross-departmental collaboration allows for the pooling of knowledge and resources, enhancing learning and effectiveness.

- **Adaptability to regulations is necessary:** Manoeuvring through regulatory obstacles, especially in historically or culturally significant structures, necessitates innovative strategies and an adaptable licencing approach. Adaptability means finding a balance between renewable energy goals and environmental preservation, involving stakeholder engagement. But also, it refers to navigating through ownership and property structures and trying to ensure consensus in order to implement building refurbishment or connection to district heating. Moreover, to increase the attractiveness of getting mortgage loans for energy renovations, regulations and financial incentives should be aligned, which can support the market transformation.
- **Embrace data-driven decision-making:** Integrating data-driven decision-making processes into city planning, facilitated by digital platforms and smart technologies, facilitates effective and informed strategies for sustainable initiatives. Across the projects, there is an emphasis on data-driven decision-making processes, particularly, to provide evidence of the impact of the planned solutions.

  Yet, providing data is a sensitive topic, staff are not always trained in appropriately managing data and projects had difficulties collecting enough data. Questions about data ownership and accessibility need to be addressed before the project starts or the data is collected. Additionally, it is important to address data sharing with participants and how data can be shared without breaking the privacy of citizens. Addressing the topic of data and educating citizens on what will happen with their data might make them more willing to share it. Lastly, the city and/or project managers must assess how they want to deal with data and acquire the skills to do so. For example, clear protocols for data ownership, accessibility, and sharing, as well as addressing privacy issues should be created at the very beginning of the project [8].
- **Prioritize long-term planning and monitoring:** Implementing sustained monitoring and evaluation strategies provides continuous improvement insights, a deeper understanding of actual impact, and informed decision-making for upcoming sustainable interventions. These lessons underscore the essence of collective collaboration, adaptable strategies, and technological innovation in achieving of sustainable and intelligent urban development. They also emphasise the need for collaboration, flexible planning, and the use of advanced technology for smart cities.

7. Summary and Outlook

This report has presented a consolidated analysis and impact assessment of four SCC projects, namely SmartEnCity, Sharing Cities, mySMARTLife, and RUGGEDISED. It identifies several key findings and lessons learned that can inform future research, policy, and practice in the field of smart and sustainable cities.

Firstly, the SCC projects have significantly contributed to advancing the state-of-the-art in urban innovation, particularly in the areas of energy efficiency, renewable energy, mobility, ICT, citizen engagement, and governance. They have demonstrated the feasibility, scalability, replicability, and sustainability of various smart solutions, as well as their potential to enhance the quality of life, social inclusion, and economic growth in urban areas.

Secondly, the SCC projects have generated valuable knowledge and data that can support evidence-based decision-making, monitoring, and evaluation of urban policies and strategies. They have developed various tools, platforms, and indicators that can help cities measure and benchmark their performance, identify their strengths and weaknesses, and learn from each other's experiences. They have also fostered a culture of collaboration, co-creation, and co-learning among different stakeholders, including citizens, businesses, academia, and public authorities.

Thirdly, the SCC projects have a demonstrated impact on achieving European climate and energy goals, such as reducing greenhouse gas emissions, improving air quality, and enhancing climate resilience. The projects have made significant contributions to these goals, although their impacts vary depending on the context, scale, and scope of the interventions. On the other hand, there are some challenges and barriers that need to be addressed, such as the lack of political will, regulatory frameworks, and financial resources to support the replication and upscaling of the projects.

Considering these findings, we recommend that future research, policy, and practice in the field of Smart Cities and Communities should focus on the following priorities:

- Strengthening the linkages between urban innovation and climate action by aligning the objectives, targets, and indicators of smart city projects with the global and local climate agendas and by integrating them into the urban planning and governance processes.
- Enhancing the social and environmental sustainability of smart city solutions and business models by ensuring that they are inclusive, equitable, and participatory and by ensuring that they do not have negative impacts on the environment, public health, and social justice. This requires a holistic and integrated approach that considers the interdependencies and trade-offs between different dimensions of sustainability as well as the diversity and complexity of urban contexts.
- Scaling up and replicating successful smart city solutions and business models by creating favourable conditions and incentives for their adoption and diffusion and by leveraging the potential of digital technologies, data analytics, and artificial intelligence to optimise their performance and impact. This requires a collaborative and multi-stakeholder approach that involves different actors and sectors and builds on the SCC projects' existing knowledge and experience.
- Strengthening the capacity and skills of urban stakeholders to design, implement, and evaluate smart city projects by providing them with access to training, mentoring, and networking opportunities and fostering a culture of innovation, experimentation, and learning. This requires a supportive and enabling environment that values and rewards creativity, risk-taking, and continuous improvement and that recognises the importance of human capital and social capital in the success of smart city projects.

In conclusion, this report has shown that the SCC projects have significantly contributed to advancing the state-of-the-art in urban innovation, generating valuable knowledge and data, and achieving climate goals. There is still much to be done to ensure that smart and sustainable cities become a reality for all citizens. This report can serve to inspire and inform future European research and innovation initiatives, policies, and practices in this exciting and dynamic field.

Acknowledgement

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Table 14: Websites of Smart Cities and Communities (SCC) projects

SCC projects	Project website
mySMARTLife	https://www.mysmartlife.eu/mysmartlife/
Sharing Cities	https://sharingcities.eu/
SmartEnCity	https://smartencity.eu/
RUGGEDISED	https://ruggedised.eu/

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Annex 1: Overview of the funding programme and call topics of the SCC projects

Table 15: Details of the 18 SCC projects (Source: Cordis)

Topic SCC-1-2014 - Smart Cities and Communities solutions integrating energy, transport, ICT sectors through lighthouse (large-scale demons–ration - first of the kind) projects Focus on fostering European Smart Cities and Communities	**Topic SCC-1-2015 - Smart Cities and Communities solutions integrating energy, transport, ICT sectors through lighthouse (large-scale demons–ration - first of the kind) projects** Focus on fostering European Smart cities and Communities; societal challenges – secure, clean, and efficient energy	**Topic SCC-1-2016-2017 - Smart Cities and Communities lighthouse projects** Focus on societal challenges – secure, clean and efficient energy, reducing energy consumption and carbon footprint by smart and sustainable use	**Topic LC-SC3-SCC-1-2018-2019-2020 - Smart Cities and Communities** Focus on societal challenges – secure, clean and efficient energy, foster European Smart cities and communities	**HORIZON-MISS-2021-CIT-02-04 - Positive Clean Energy Districts** Focus on implementation of the Climate-Neutral and Smart Cities Mission
Call H2020-SCC-2014	**Call H2020-SCC-2015**	**Call H2020-SCC-2016**	**Call H2020-LC-SC3-2018-ES-SCC**	**HORIZON-MISS-2021-CIT-02**
GrowSmarter Transforming Cities for a smart, sustainable Europe (1 January 2015 – 31 December 2019)	**REPLICATE** Renaissance of Places with Innovative Citizenship and Technology (1 February 2016 – 31 January 2021)	**RUGGEDISED** Rotterdam, Umea and Glasgow: Generating Exemplar Districts in Sustainable Energy Deployment (1 November 2016 -31 October 2022)	**CityxChange** Positive City ExChange (1 November 2018 - 31 October 2023)	**ASCEND** Accelerate poSitive Clean ENergy Districts (1 January – 31 December 2027)
Triangulum The Three Point Project/Demonstrate. Disseminate. Replicate. (1 February 2015 - 31 January 2020)	**SMARTER TOGETHER** Smart and Inclusive Solutions for a Better Life in Urban Districts (1 February 2016 - 31 July 2021)	**mySMARTLife** Smart Transition of EU cities towards a new concept of smart Life and Economy (1 December 2016 – 30 September 2022)	**MAKING-CITY** Energy efficient pathway for the city transformation: enabling a positive future (1 December 2018 - 30 November 2023)	**Neutralpath** Pathway towards Climate-Neutrality through low risky and fully replicable Positive Clean Energy Districts (1 January – 31 December 2027)
REMOURBAN Regeneration Model for accelerating the smart URBAN transformation (1 January 2015 – 30 June 2020)	**SmartEnCity** Towards Smart Zero CO_2 Cities across Europe (1 February 2016 – 31 July 2022)	**STARDUST** Holistic and integrated urban model for smart cities (1 October 2017 - 31 March 2024)	**SPARCs** Sustainable energy Positive & zero carbon Communities (1 October 2019 – 30 September 2024)	
	Sharing Cities Sharing Cities (1 February 2016 – 31 December 2021)			
		Call H2020-SCC-2017	**H2020-LC-SC3-2019-ES-SCC**	
		STARDUST Holistic and integrated urban model for smart cities (1 October 2017 - 31 March 2024)	**SPARCs** Sustainable energy Positive & zero carbon Communities (1 October 2019 – 30 September 2024)	
		MatchUP Maximizing the Upscaling and replication potential of high-level urban transformation strategies (1 October 2017 – 30 September 2023)	**POCITYF** A Positive Energy CITY Transformation Framework (1 October 2019 - 30 September 2024)	
		IRIS Integrated and Replicable Solutions for Co-Creation in Sustainable Cities (1 October 2017 - 31 March 2023)	**ATELIER** Amsterdam Bilbao Citizen driven smart cities (1 November 2019 - 31 October 2024)	
			Call H2020-LC-SC3-2020-EC-ES-SCC	
			RESPONSE Integrated Solutions for Positive energy and resilient Cities (1 October 2020 - September 2025)	