Ref. Ares(2019)2768779 - 24/04/2019

RUGGEDISED

Designing smart, resilient cities for all

EUROPEAN COMMISSION

Horizon 2020

H2020-SCC-2016

GA No. 731198

Deliverable No.	6.2	
Deliverable Title	“Rich narratives” – Scenario analyses for the Lighthouse cities and recommendations	
Dissemination level	PU	
Lead participant	RISE	
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Status	FINAL	

H2020-SCC-2016 – Grant Agreement number 731198 - RUGGEDISED

Acknowledgement:

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

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Disclaimer:

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

Executive summary

This Deliverable 6.2 “Rich narratives” – Scenario analyses forthe Lighthouse cities and recommendations summarizes the process and outcome of Task 6.3 “Contextual Scenario analysis”. The work was carried out during October 2017 – November 2018.

The deliverable describes one “rich narrative” of a plausible and relevant future each for the lighthouse cities of Umeå, Glasgow, and Rotterdam for the year 2033, specifically by providing a maximum credible upscaling potential of the smart solutions, thereby fulfilling the expectations of the project stakeholders and the description in the Grant Agreement.

The analysis was performed in close cooperation with each lighthouse city, using foresight and innovations system analysis, notably through (1) interviews with smart solution stakeholders, (2) the creation of the visualisation tool UPSCALE (Upscaling System) to determine the upscaling potential of the technical solutions and innovations, and (3) the execution of one workshop for each city, capturing unique conditions and providing each city with a future image, helping determine which options for action are most robust.

The results in Deliverable 6.2 will influence Task 6.1 “Innovation Platforms” and serve as an input to Task 6.4 “Assessing the long-term scaling potential and energy system effects of the light house smart solutions”.

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Introduction

The aim of Task 6.3 "Contextual Scenario analysis" was to produce "rich narratives" of plausible, relevant futures, and to help lighthouse cities determine which options for action are most robust.

To accomplish this, it was agreed by the relevant RUGGEDISED stakeholders at the kick-off of WP6 "Enabling upscaled deployment and business model innovation" on 12-13 October 2017, after recognizing that the conditions, barriers and drivers of each city are vastly different, to slightly re-focused the task from producing a set of common scenarios to instead producing one unique future scenario for each lighthouse city.

Consequently, one future scenario for Rotterdam, Umeå, and Glasgow was produced, looking 15 years ahead to describe the overall socio-political landscape of each city, including dimensions from the energy, environment, and urban innovation systems, while describing feasible and maximum desirable levels of upscaling for the solutions demonstrated in WP2 "Challenges and Solutions Rotterdam", WP3 "Challenges and Solutions in Umeå", and WP4 "Challenges and Solutions in Glasgow", respectively.

Method

To develop the three future scenarios, foresight and innovation system analysis methods were applied and three scenario workshops were held.

Each workshop was prepared in the same manner. First, in the weeks leading up to the workshop project representatives responsible for one or more of solutions were interviewed according to the CCC (Context and Critical Conditions)[1] framework, which also serves as the basis for WP 6.5's Urban Innovation Systems analysis.

Second, a participant-driven workshop process was developed to capture both the systemic conditions of each city, and the level of upscaling relevant for each city's solutions. The aim of each workshop was to identify and develop one plausible scenario 15 years ahead, when the RUGGEDISED smart solutions had been upscaled to a simultaneously feasible and maximum desirable level. STEEP-analysis, drivers and barriers, and trend discussions were included, though the core of the design was the the UPSCALE system (see below), which project representatives worked through together.

Finally, the results of the workshops, combined with the findings from the preceding interviews, enabled the write-up of the "rich narratives" for each city, then was circulated among relevant stakeholders for comments.

1.1 UPSCALE (Upscaling System)

During the first round of preparatory interviews with representatives of the solutions in Umeå, it became clear that the matter of upscaling had several meanings and dimensions. Therefore, the study team developed a physical visualisation tool – the UPSCALE (see
Figure 1: UPSCALE) – that could be adjusted ahead of each workshop to fit the conditions for each city and the varying RUGGEDISED solutions.

[1] https://www.ea-stmk.at/documents/20181/25550/ECOPOL+Context+and+Critical+Conditions+-+review+2014.pdf/d7a3069f-6db9-45a4-aa51-fddb6b247578

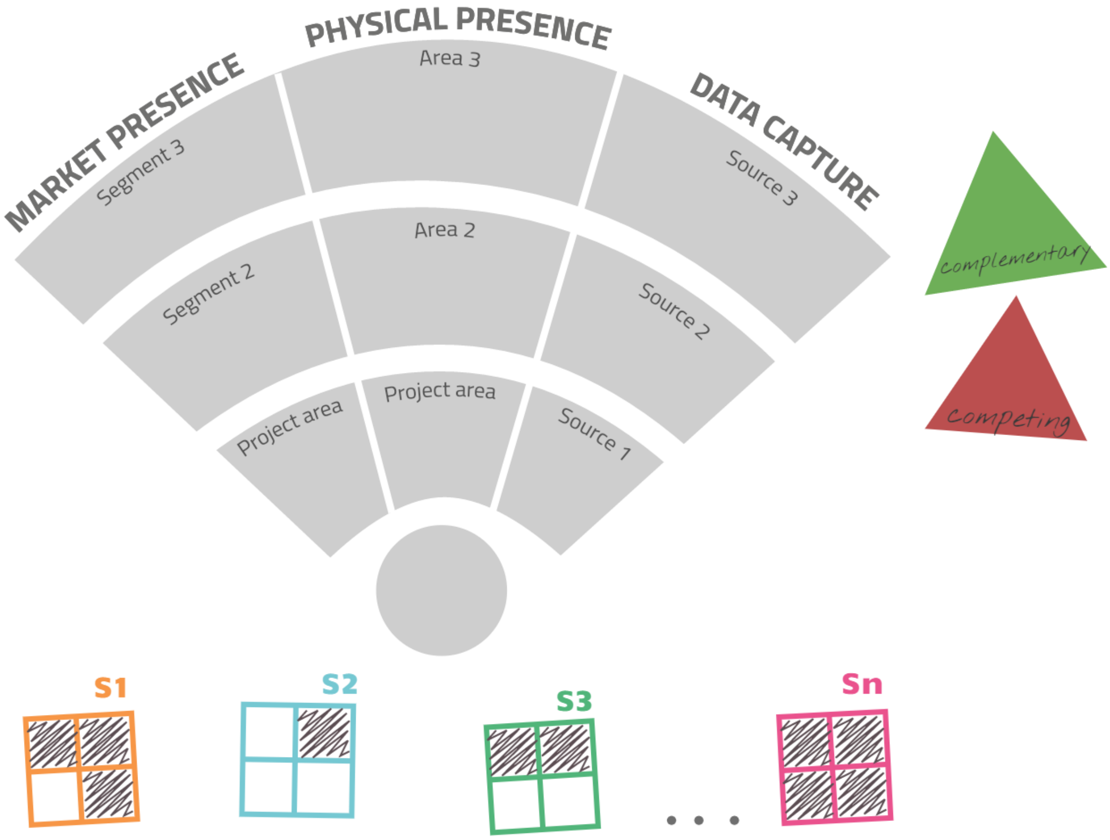


Figure 1: UPSCALE

UPSCALE works in the following way. For each solution (S1, S2, and so on), participants have square paper pieces of a different color, on which they indicate the approximate degree (in 25%, 50%, 75%, 100% intervals) of expected future upscaling across three relevant dimensions:

- Market presence: the expected *maximum and desired* market share captured by the innovation. In order to avoid the pitfall of false specificity, the level was not specified in terms of revenue, number of customers acquired etc.; instead a general assessment of market share in % was agreed.
- Physical presence: the expected *maximum and desired* geographical spread/connectedness of the smart solution. Again, no specific indicator (number of buildings connected, number of streets/neighborhoods/residents using the innovation) was specified, as these vary across solution and were deemed to specific for a qualitative exercise with a 15-year time horizon. Instead a general assessment of 'coverage', in percentage terms, was agreed by participants.
- Data capture: the expected *maximum and desired* inclusion of relevant digital data. Here no indicator (number of descrete sets, terabytes, executed calls on databases etc.) was identified; instead a general assessment of data inclusion, in percentage terms, was agreed by participants.

Participants agree on an estimated level of upscaling for each relevant scope (from closest to project remit and outwards). Triangle paper pieces are also made available to indicate complementary (green) and competing (red) solutions and their relevant dimension and scope.

It is possible in further analysis to use the value to derive more precise indicators of upscaling potential, especially where other relevant quantification is available and modelling can be done. Participants in UPSCALE did not do so, but such an effort is being undertaken in task 6.4.

1.2 Workshops

The first workshop was held in Umeå on 5 December 2017, the second in Glasgow on 22 March 2018, and the third in Rotterdam on 21 June 2018. Each workshop was led by RISE and hosted by the city, and included key stakeholders from the city and the RUGGEDISED solution.

Figure 1 - Workshop in Umeå 5 December 2017

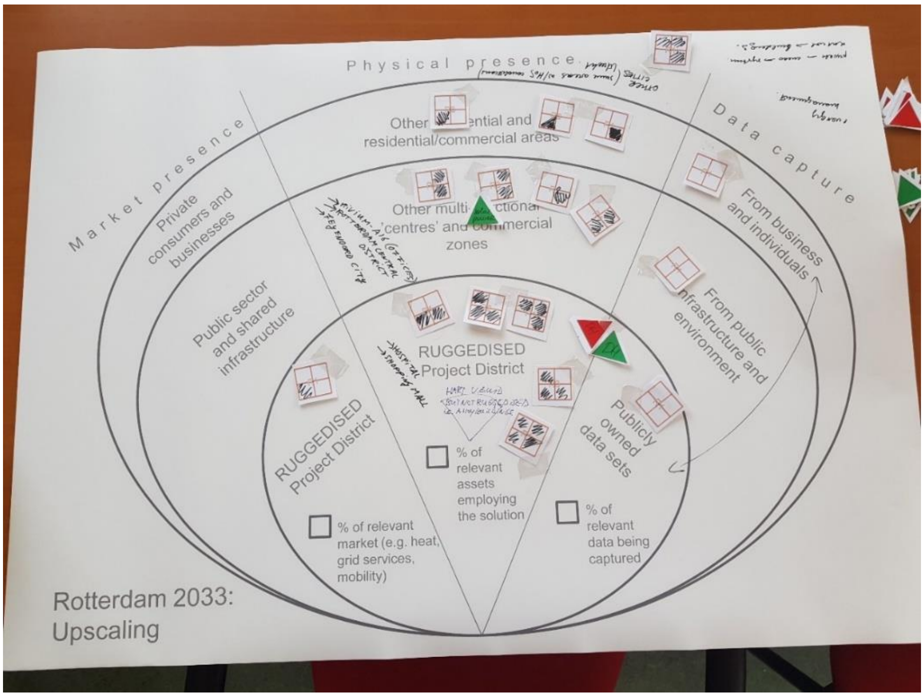


Figure 2: UPSCALE analysis completed for Rotterdam

Upscaling Scenarios

1.3 Umeå in 2033

In 2033, Umeå is a city bursting at its seams, with a population closing in on 200 000, having grown by 10% per year for more than a decade. Umeå is at the forefront of digitalisation and considered one of Sweden's smartest cities, in large thanks to its public actors' ability to provide direction and promote innovations that put the common good first. The city has remained an attractive destination for both visitors and people looking to work or study. Air quality, once a cause of concern, is now at a high standard.

Many of Umeås innovations revolve around energy, a focal point of one of the cities most successful co-operations in the EU RUGGEDISED-project. Energy provision is gloriously renewable in many parts of the city, no small feat, considering the temperature variations throughout the year. Roughly half of Umeå buildings employ advanced strategies for using energy intelligently. Umeå is a city of sensors and control systems, which consider outside and inside climate and the behaviour and needs of inhabitants and occupants, when measuring, predicting and intelligently adjusting heating, lightning, and so on. Nonetheless, some areas remain un-upgraded and un-optimised.

The city centre is electrically silent, and the few e-cars and occasional delivery vehicles go about their business without disrupting conversations among pedestrians who can now hear each other without a problem. People and places to meet and drink are now the most distinctive landmarks on the city-scape, rather than roads and traffic noise. Public transport is still present, of course, making its more common presence known with a whooshing movement of air. Yes, buses are electrical, as are their stations. And they are both warm. Or cold, depending on the day.

The citizens of Umeå rave about the proximity of everything, from services and shops to cafés and night life. "If you're in the city centre, you can walk almost everywhere, and the rest can be reached by bicycle!" people say, and they used to add dryly, "If the weather allows." Citizens of Umeå love being active, and for many the most important amenity of all is Umeå's closeness to nature and the multitude of leisure activities available, including cross-country and downhill skiing.

These days the newly heated and covered cycle paths make the weather less of a factor when going to work or school. Property developers and owners market houses that have a small climate impact, while citizens speak even more highly of the good living conditions and cooperative spirit, and many still feel that Umeå is a city where anything is possible. As a student at the university campus said recently, "Umeå has a bright future ahead!"

The thing was, Umeå in the 2010s was a city struggling with air pollution and not as sustainable as its citizens and government had hoped. The easy access by car had led to increase in traffic most years, and the car was a key component in making the city feel accessible. And while it was believed that Umeå had reached its peak of energy consumption, there was no peak car use in sight. Riding a bike had for many a low social status, and it was clear that it was easier and preferable to take the car.

Over the years, as Umeå city developed and open areas were exploited, the city became denser, in line with political goals. However, contrary to political goals, car use in the city continued to increase. While the new ring road pushed some individual car use outside the city and zero-carbon fuels public transport was extended, it was not enough to off-set the rising population. More bicycles were measured on the roads every year, slowly but steadily gaining market share thanks to trends of healthy lifestyles. Perhaps these cyclists were contributing to the increasingly vocal demands for more influence over the city development. But they were not alone. "We just want a healthier city to live in!" exclaimed a senior citizen, walking poles in hand, outside the city hall.

So it was that in the mid-2020s developments accelerated. Umeå adopted a clear vision for 2040. It painted a picture of an Umeå whose ambitious goals for social and environmental sustainability and increased business viability had been realised, and where Umeå remained an equal and inclusive city. In this vision the city government continued to engage with its citizens in creating a flourishing city building on Umeå's unique characteristics, its climate and location, its active life-styles and the creative energy coming from the university. A clear road-map for getting to the vision was drawn up, with an action-plan for the immediate next steps. "And finally, we just said, let's go!" the mayor at the time told curious reporters at a press conference. Meanwhile, on the stairs outside a baffled teenager exclaimed "I can barely believe it's happened!"

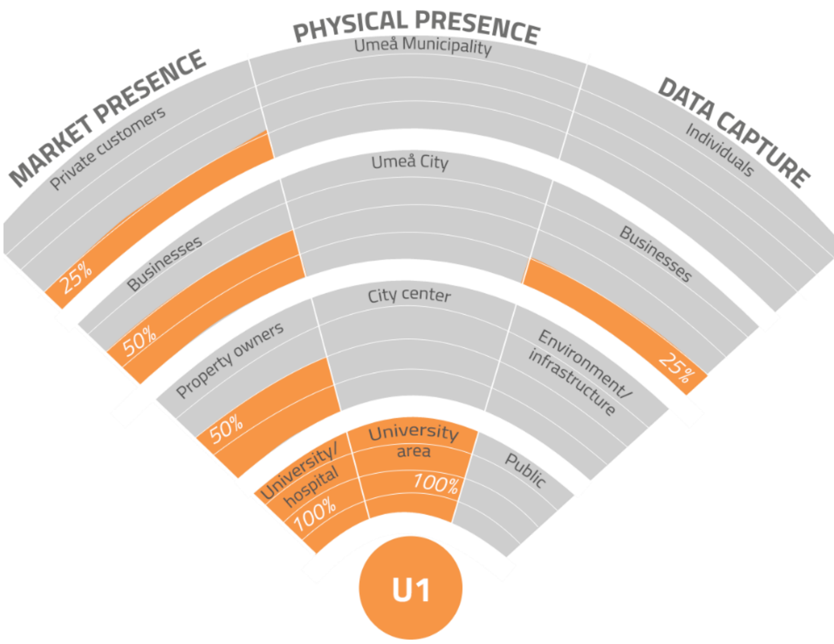
In the next years, city centre reforms were put in place. Transport of goods was banned, with only electric vehicles allowed. A strict limit on parking spaces was introduced and the creation of green bicycle passages in the city. Together, the municipality and its locally owned companies cooperated with local business, the hospital and the University, to create a systemic pressure on resource flows to become frugal and optimized and leverage the opportunities created by technological developments. Public transport actors felt pressure from the public and politicians alike to finally integrate ticket systems and data to decrease overall complexity. Economically sustainable solutions and services are encouraged and gain traction thanks to the willingness of inhabitants in Umeå to change their consumption patterns.

1.3.1 Umeå's RUGGEDISED solutions, scaled up.

Several developments (in the economy and society) and initiatives (from the city and its stakeholders) that were already underway during the mid-2010s continue to have implications for how energy and mobility needs are fulfilled in Umeå in 2033.

1.3.1.1 Smart City connection to 100% renewable energy (U1)

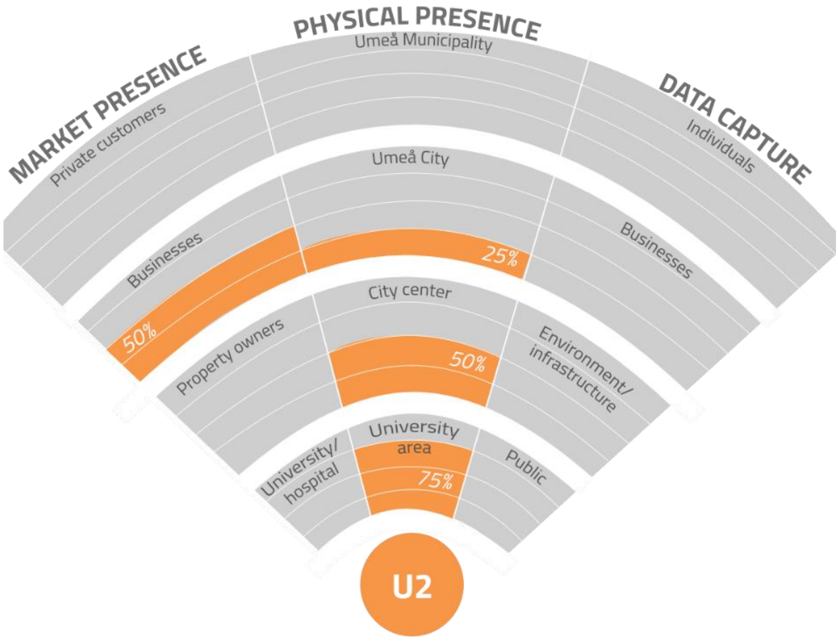
Energy provision in Umeå is greener than ever and increasingly democratised. The university campus energy needs for heating, cooling and electricity (kWh)are met by 100 % renewable energy supply, whereas as the market share in the rest of Umeå varies from roughly 50% among commercial and public properties to roughly 25% among individual customers. Linear energy business models from producer to consumer are becoming a thing of the past; in the business model of 2033 the local energy supplier is a buyer of energy (from e.g. local solar installations and bore-holes), a seller, a producer and a key enabler in the highly optimized energy flows of the city. Investments and risk are now shared among many actors, but so also are also revenues and profits.



Smart City connection to 100% renewable energy

1.3.1.2 Peak load variation management and peak power Control (U2)

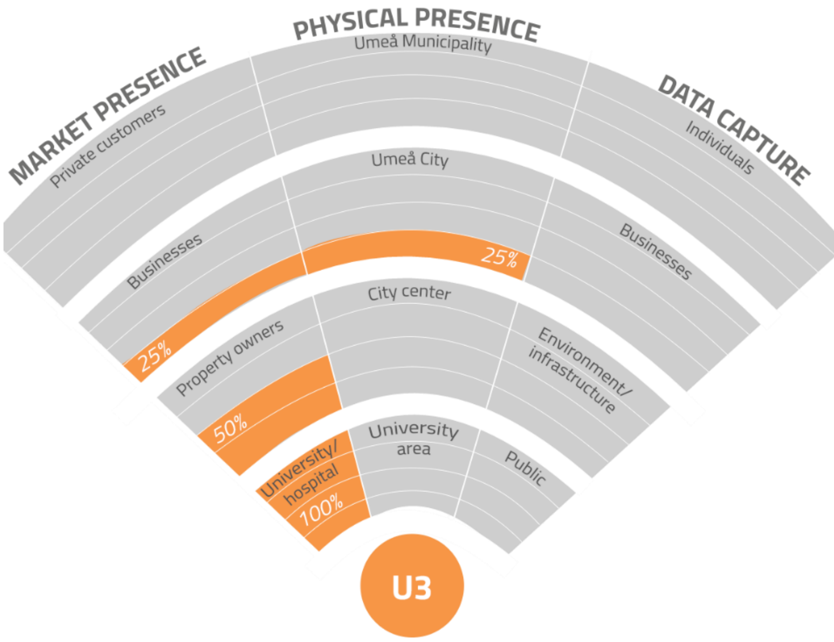
There is now capacity to mostly handle energy demand with renewable energy even during peak hours. This is possible thanks to the use of buildings as thermal energy storage and the smarter energy system, where sensors and energy management units have been installed to reach about 75 % of the geographical university campus area, 50% of the Umeå city centre area, and 25 % of the rest of the Umeå urban area.



Peak load variation management and peak power control

1.3.1.3 Geothermal heating/cooling storage (U3)

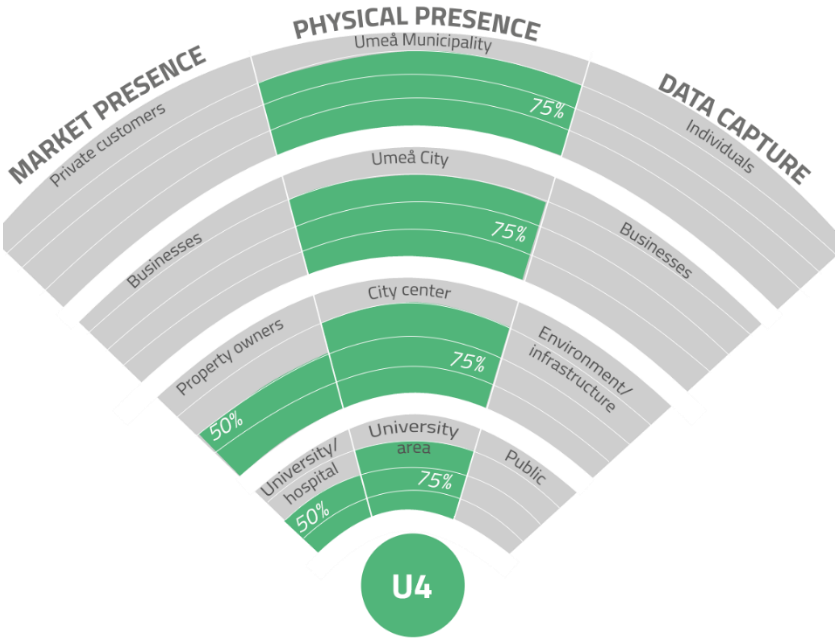
The installation of bore-holes under a parking lot at the hospital grounds in the 2010s met the complex's growing needs for comfort and process-cooling. Today energy storage can be found both centrally and locally, such as in connection to buildings and e-hubs, enabled by the energy system's capacity to handle flows of energy in and out. Geothermal storage units can be found in approxmately a quarter of Umeå geographical urban area, with new business models for peer-to-peer exchange securing the delivery of heat and cold during the extreme variations of climate/temperature over the four seasons in Umeå (+30C to -30C), enabling 100% of the energy consumed in the University campus area, 50% among property owners and 25% among businesses, to be from geothermal heating.



Geothermal heating/cooling storage

1.3.1.4 Intelligent building control and end user involvement (U4)

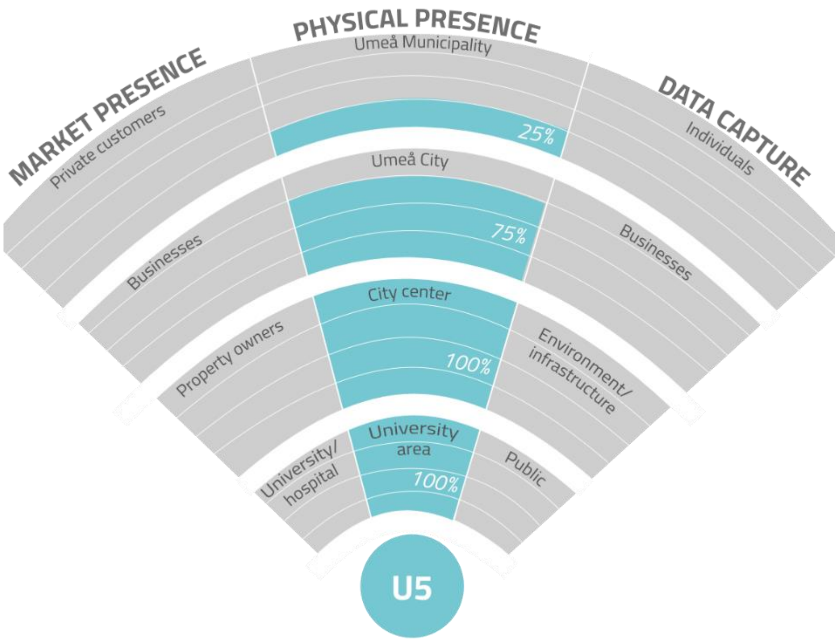
Many buildings and offices in Umeå are controlled intelligently, with improved control systems for internal climate installed in new apartments and retrofitted to old buildings to reach 75 % percent of buildings in the municipality. At the university campus, in the hospital buildings and in public and commercial properties these systems impact as much as 50% of energy consumption. They optimize energy use / energy savings through setting of modes: "away", "sleeping" etc. for heating, fans, lightning, and climate.



Intelligent building control and end user involvement

1.3.1.5 Energy optimised electric BRT-station (U5)

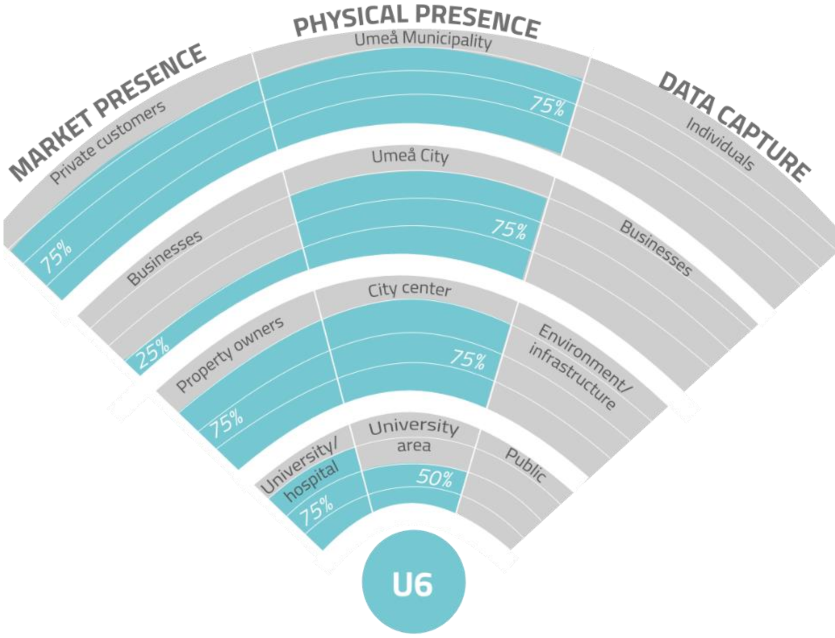
Electrical buses and electrical bus rapid transit stations are fully developed in the city centre, and reach about 75% of the rest of the geographical area of the municipality. An intelligent ticket identification system using smartphones before boarding combines with new insulation structures to minimize energy losses during boarding and disembarking. Self-driving electric cars, bicycles, and self-driving buses complement the main bus system.



Energy optimised electric BRT-station

1.3.1.6 E-charging infrastructure hubs (U6)

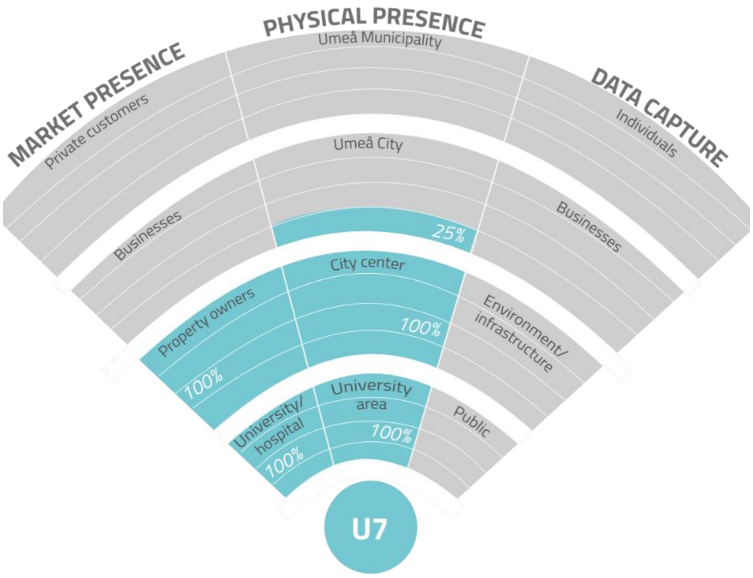
E-hubs are wide-spread, and about 75 % of Umeå municipality, and 50% of the university campus, has an e-hub within walking distance. This has been a driver in the local deployment of solar cells and batteries and has led to a prioritization of electrical solutions in mobility management, as well as the development of attractive e-mobility package offers. Citizens in proximity of the e-hubs almost exclusively choose to use either an electric bike, electric shared car, or taxi, when going to work or doing errands close to or within the city, even if complete coverage of all destinatoins is still some years away. E-hubs meet about 75 % of transport needs on the university campus, as well as elsewhere in the city, though businesses make less use of them for their needs.



E-charging infrastructure hubs

1.3.1.7 Energy-efficient land use through flexible green parking pay off (U7)

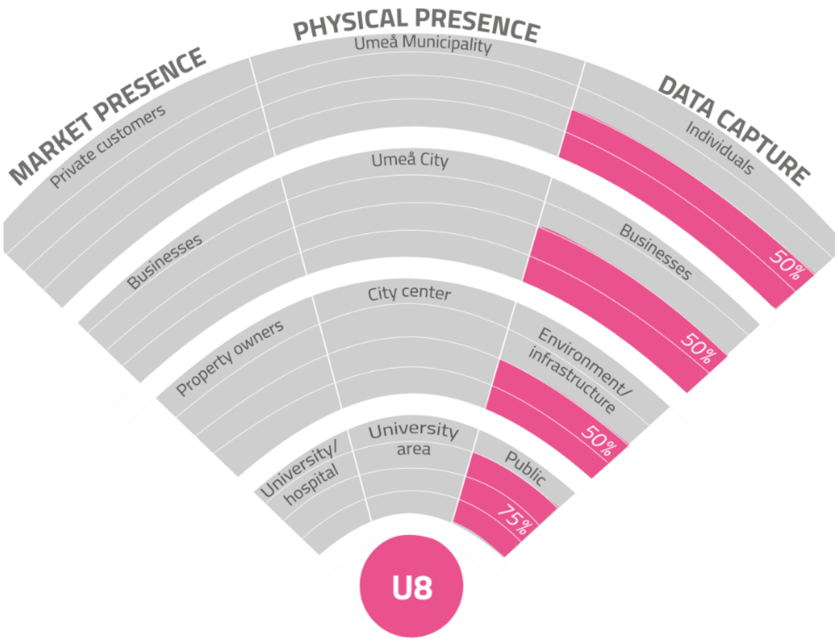
All projected new parking spots in the Umeå city centre and 25% in the rest of Umeå urban area, among property owners and on the university campus, have been exchanged through this scheme, so that new parking spots arise only outside the city centre. This limits the attractiveness of owning a car in Umeå and driving to and from the urban area. Through self-driving shared cars there is still individual transport available in and out of the city, but this volume is not comparable to peak car volumes from decades previous.



Energy-efficient land use
through flexible green parking pay off

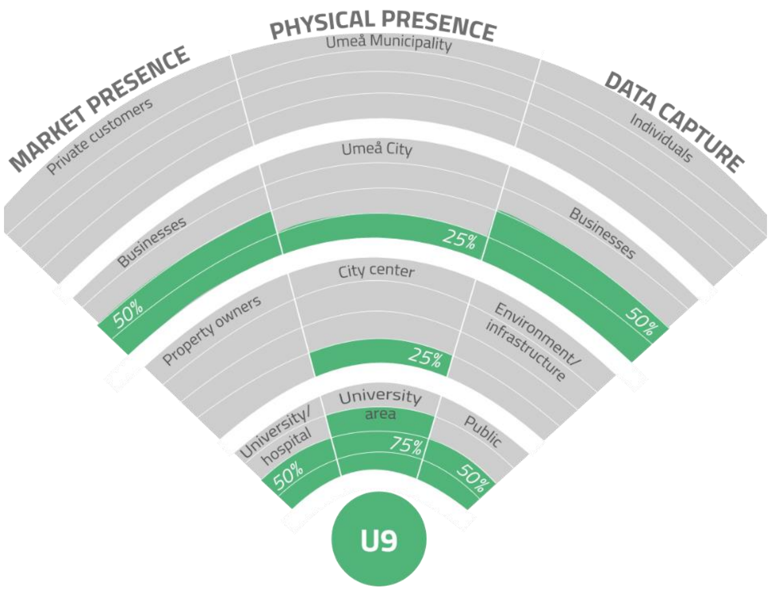
1.3.1.8 Smart Open Data City Decision platform, Co-creative design platform (U8)

The collection and integration of the data provided by infrastructure around Umeå is at an all-time high, enabling the monitoring and smart adjustment to the city's energy consumption, energy production, and its buildings and technologies involved, even taking into consideration human behaviors. That data is complemented by non-technical artefacts such as business models and support processes. These different sorts of data provide energy savings through collaboration and knowledge, integrating some 75 % of public digital data sets (e.g. data on energy use, population data, emissions data, etc.) with 50% of digital data sets in surrounding environment and infrastructure, business and individuals. Some data sets are problemating under strengthened EU-guidelines on privacy and have not been integrated.



1.3.1.9 Demand-side management (U9)

Thanks to sensors and the constant study and prediction of the flow and behaviour of people, active management of space use is available in more than a quarter of city buildings and has a market share, i.e. is being used by 50 % of potential customers, on the university campus and among businesses. This has led to lower energy consumption when facilities are off peak, as well as the optimisation of building services such as cleaning and maintenance, making an expansion of students, academics and inhabitants possible without a proportionate rise in space and energy.



1.4 Glasgow in 2033

In the year 2033 the city of Glasgow is awash with new energy. Not energy from the sun, wind, or batteries, though these are more important than ever, but energy from residents, authorities and local businesses who are turning the city into a European model of smart and inclusive sustainability. Rather than peaking or dissipating, the vibrancy of the cultural and economic renaissance of the turn of the 20th century has found new outlets in projects for smarter energy and more sustainable mobility.

New infrastructure is being built – both visibly and invisibly. Heating of buildings, long the sticking point in the battle to end energy poverty and move away from fossil fuel dependency, is being transformed by a diverse range of solutions in different neighborhoods. Electricity, once the inscrutable product of distant power plants and national monopolies, has also become a community-centric service, with batteries, renewable power systems, and demand side management operated by a diverse range of energy service companies with varying business models, both for-profit and public interest. Fossil-fuelled personal cars have been banned from the city centre; electric cars are now joined on the streets by the first buses using hydrogen fuel cells. But the traffic is less overall, the air is cleaner and quieter during the days and the pavements better lit at nights, with smart lampposts used to charge electric bicycles, the preferred mode of transport for the city's students and younger residents. Behind these transformations lies a new data infrastructure, with sensors and algorithms informing a planning system that prioritizes efficiency and system stability.

The energy for change had bubbled under the surface for years, since before the first RUGGEDISED solutions were put in place. Costs for renewable energy systems, and particularly battery storage, were falling rapidly, and there was increasing interest in exploiting the potential for small-scale, low-carbon solutions. New algorithms for managing energy demand in a decentralized way were enticing energy entrepreneurs. Enthusiasm for electric vehicles ran high among Glaswegians and received a boost from the Scottish government's ambitious plans for phasing out the internal combustion engine. But the technological and societal enthusiasm for these solutions was running ahead of the infrastructural, regulatory and market capacity to deliver them. Well-off early adopters of decentralized energy and electric mobility were using up grid capacity – making these same solutions more expensive for the less well-off, rather than reducing their costs. And the risks inherent in changing these systems were holding back sustainable Glasgow.

Proactive players were needed, and the Glasgow City Council took a pivotal role. The journey towards a sustainable Glasgow has fundamentally altered the GCC's identity; while maintaining its traditional role as a city authority, in 2033 the GCC is recognized as a proactive and even entrepreneurial actor in the public interest. Starting with RUGGEDISED, the GCC's efforts to design and in some cases directly incorporate business models that generated extra benefits for local communities helped open up new energy markets, providing a trusted counterparty for traditional energy companies and smaller aggregators and allowing new kinds of risk-taking. Growing confidence in these models boosted support for political changes at the national level that transformed rate-setting and created new opportunities for system operators. This positive feedback loop was even stronger for Transport Scotland, whose practical initiatives to stimulate markets for electric mobility were crucial to meeting political goals both nationally and in Glasgow.

These changes were not smooth or linear, and the GCC, Scottish Power and Transport Scotland rode out some turbulent times and failed initiatives. In 2033 energy poverty has been significantly reduced, but not as rapidly as had been hoped, with planning and grid constraints slow to resolve despite these organisations' proactivity. Technological change has not always benefited the first movers, with vehicle charging facilities and some forms of district heat particularly vulnerable to competing solutions and obsolescence. But through their initiative-taking these organisations improved their own ability to adapt and change, and to work with communities, suppliers and customers in productive ways towards the promise of a more sustainable Glasgow to come.

1.4.1 Glasgow's RUGGEDISED solutions, scaled up

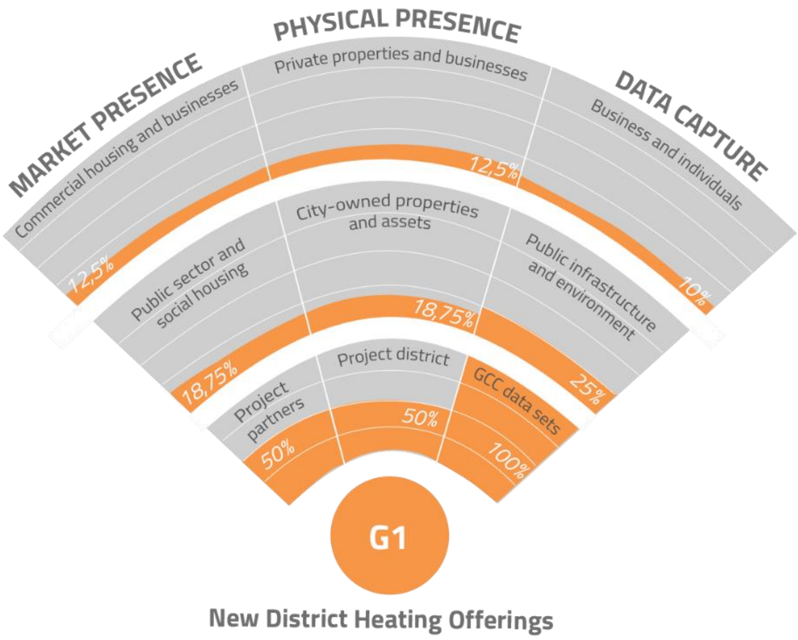
Several solutions -- and combinations of solutions -- being demonstrated in the late 2010s continued to be relevant to sustainable Glasgow in 2033.

1.4.1.1 New District Heating Offerings (G1)

District heating plays a much larger role in Glasgow than it did 15 years previously, though its reach remains limited and it is not based on a single generation technology. About half of the heating demand in the original RUGGEDISED project district is distributed via the district heating network, with heat sources coming from industrial and municipal waste heat. City-owned properties and social housing in Glasgow get about 20% of their overall heat via local district heating grids, while the remainder of private and commercial properties are connected at only about a 10% rate. Energy efficient new buildings and low-heat resources are connected to these grids via heat pumps in a range of sizes and configurations. In recent years local grids have been commissioned to connect to deep geothermal heat, which shows promising economics. A new demonstration zone has been created to test pure peer-to-peer transactions using heat in district grids; these systems are fully automated and transactions are based on blockchain.

District heat's impact has been limited by geography, as Glasgow's growth to the lower-denisty periphery made such networks less attractive, and in some cases by planning restrictions, which were only gradually lifted over the period. More happily, the demand for heating in general has declined, as new builds are passive buildings with no net heating requirements, and retrofits have driven up energy efficiency in social housing. Much new demand in private housing and commercial buildings is met by heat pumps.

The economics of district heating were improved greatly by a new regulatory regime, which provided rate payers some insulation from high fixed costs of the networks and allowed energy service companies (ESCOs) to more successfully seek new customers for connections. The most important of these ESCOs was formed by the Glasgow City Council itself, and is still in operation, serving social housing units connected to two different heating networks. It was the success of this example, along with regulatory changes initiated in the national government, that was crucial to creating a market for district heating at sustainable prices from a range of different generation technologies.



1.4.1.2 RES + Battery Storage + Grid Services (G2, G3, G4)

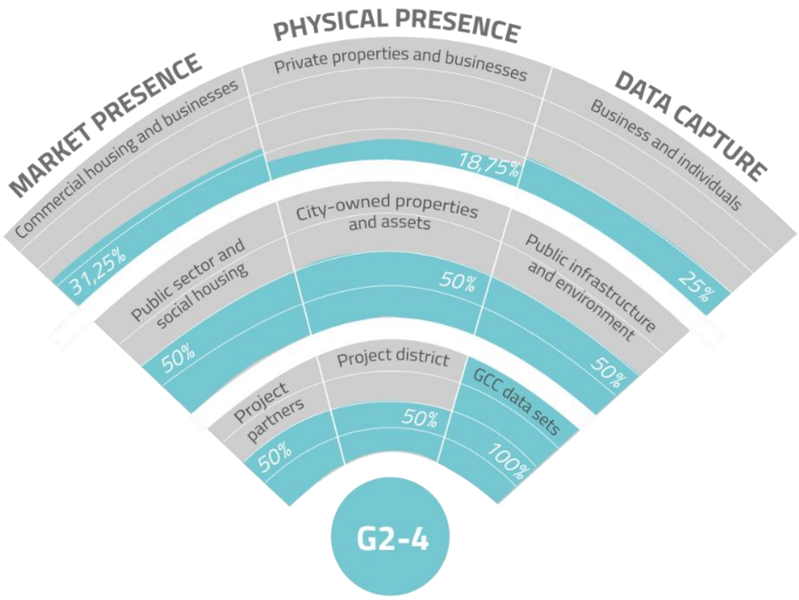
In 2033 the configuration of small-scale renewable energy generation, local battery storage, and distributed services for distribution network stabilization is on its way to becoming the dominant model in the power sector. Already 50% of city-owned buildings and social housing are connected to such systems, and these are closing in on net self-sufficiency in power. In commercial and private residential housing the uptake has been somewhat slower, with around 20% of buildings connected to distributed resources. The role of these systems is growing in importance, however: for short periods these distributed assets have accounted for as much as 50% of the city's total power market activity in terms of direct consumption, supply to the grid and balancing services. Increasingly locally-connected prosumers trade directly peer-to-peer using blockchain technology for transactions.

The technological developments that facilitated this shift were global in nature, and Glasgow as everywhere had its power market calculus changed by falling battery costs and the electrification of personal transport. As prices for green electricity from the national grid also fell, however, the driver for distributed power generation and storage in

Glasgow increasingly became the ability to provide and monetize grid stabilization services, thus capturing additional benefits locally. This monetization was achieved through the design of complex site arrangements, which were adapted for more dynamic electron flows, and implemented and managed by third-party aggregators. The RUGGEDISED project proved that this model could be executed in the context of social housing, lowering overall costs to building owners and residents. The success of this initiative was repeated across the city, as standardized technology packages and site arrangements made retrofitting relatively easy, and tightening requirements on buildings' climate and energy performance promoted uptake.

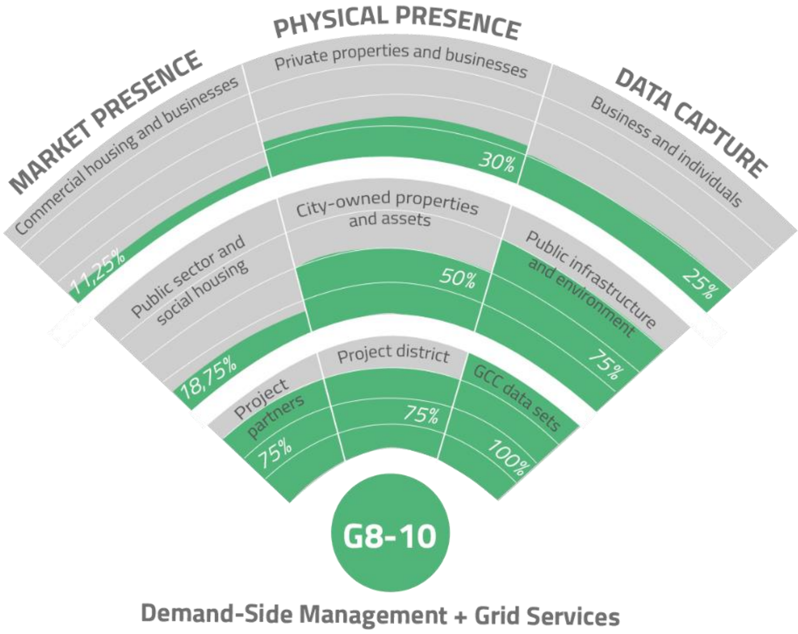
Initially, many of these local generation and storage connections were viewed more as risks than as opportunities from the network operator (DNO) perspective. Despite the potential for a load management and balancing services, battery storage also presented a technical fault risk to the distribution system that the required active management. At first these responsibilities were licensed to third parties by the network operators, but in the early 2020s the formal establishment the Distribution System Operator (DSO), with an expanded mandate encompassing management of storage assets, allowed for grid-connected storage to be rolled out more quickly. This, in turn, eased congestion in the network that had driven up the cost of grid connections and limited the spread of small-scale RES systems to that point.

In 2033 the market for power is a competition between affordable grid electricity generated largely by wind power, and efficient, economically dynamic local generation and storage systems that offer upside to those who install them. The eventual equilibrium point of this competition is still some years off, but smart, local solutions are on the rise.



1.4.1.3 Demand-Side Management + Grid Services (G8, G9, G10)

The increasing dynamism of the power markets and distribution network have also created a much larger role for demand side management (DSM). In 2033 DSM is not just about optimizing loads from large consumers; now aggregators are working with the Distribution System Operator (DSO) to provide more and more targeted balancing services for the benefit of the local network. In this way those energy consumers who do not participate in complex site arrangements can participate in the growing energy services market. On the smart street of the RUGGEDISED project, as much as 75% of energy demand is dynamically managed. Approximately half of publicly owned buildings and social housing provide some DSM-based services, though these are based on a smaller part of their energy demand overall. Nearly a third of private homes and commercial buildings have the ability to provide DSM services, though their participation in these markets is relatively limited.

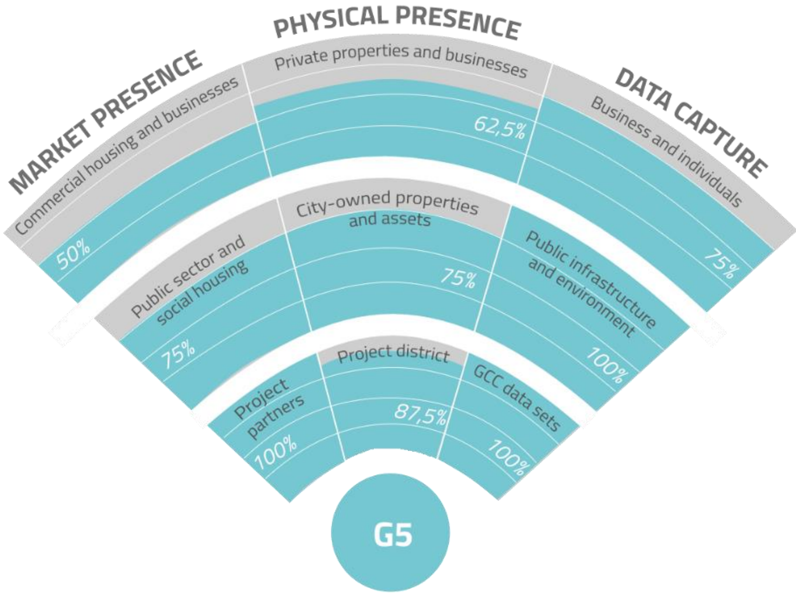


1.4.1.4 Electric vehicle charging and E-mobility services (G5)

By 2033 Scotland has achieved its goal: no new conventional petrol or diesel-powered cars were put on the road in the past year. In Glasgow, the change has been if anything more radical: the city centre is now free of personal cars, and low emission zones regulate the use of non-electric vehicles in much of the city. Electric vehicle charging, from its modest beginnings in the RUGGEDISED project, has become an almost universally available service: more than 75% of public and more than 60% of privately owned parking spaces have charging capabilities. Overall electric mobility accounts for more than half of the passenger-miles travelled within city limits. While bus fleets have not been converted to batteries, the city has begun phasing in buses powered by hydrogen fuel cells. Autonomous (electric) vehicles – both car-sharing and small publicly-operated shuttles, have been in operation for 5 years and are growing in popularity. In the university districts electric bikes – with charging paid for by the universities – have become the most popular form of transit, and these neighborhoods' pavements and roads have been redesigned to accommodate heavy cycle traffic.

Uptake for these electric mobility solutions has been enthusiastic throughout the past 15 years. Challenges did arise as demand for charging initially outpaced the network operator's approval of new charging facilities. Additionally, Transport Scotland and their partners had to absorb some technology risk as rapid advances in high-speed and wireless charging systems made some early choices prematurely obsolete. Yet these hiccups did little to undermine public enthusiasm for electric mobility, and as they were overcome demand continued to grow steadily.

Planning to meet this demand was supported by extensive data capture: the Distribution System Operator was, throughout most of the period, able to capture extensive data regarding EV use and charging demand, as data sharing was included as a condition for both car sharing services and connectivity agreements for operators of charging points.

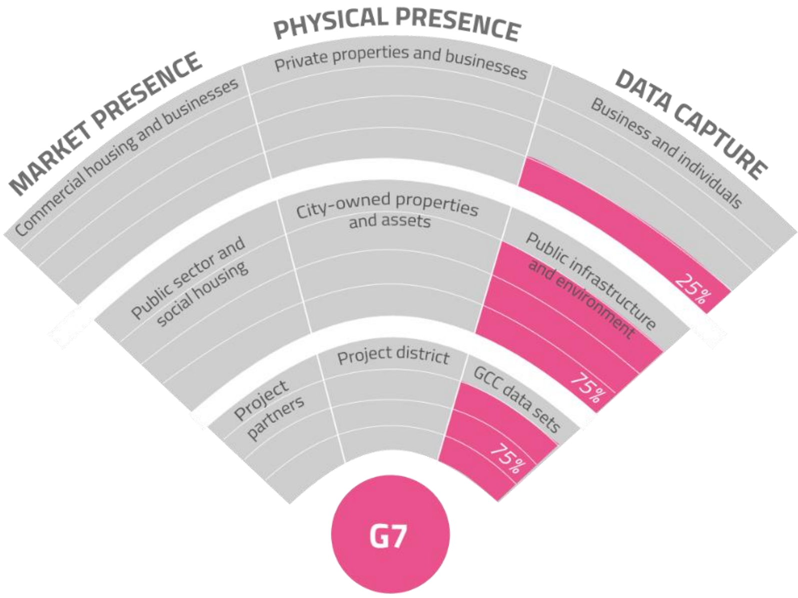


Electric vehicle charging and E-mobility services

1.4.1.5 Data-Based Decision Platform (G7)

By 2033 the Glasgow City Council has been using its Data-Based Decision Platform to inform all major planning and development decisions for almost a decade. Use of the Platform for day-to-day operational decision making is also on the rise, though this is often limited by the provision of data from business and private actors. The GCC estimates that about 25% of relevant data from the private sector is being captured in 2033, while approximately 75% of the GCC's own data sets, including from real-time streams being generated by extensive use of sensors in infrastructure and the natural environment, have been integrated. The data from these sensors are not only used within the GCC: geotagged data are commonly exported for use by business, community and environmental organisations.

Advances in machine learning and artificial intelligence have brought significant opportunities to use the Platform for automation. In some applications, like intelligent street light management, this has long been standard practice, with resulting gains in both economic efficiency and citizen satisfaction. In other areas, including in energy markets and traffic control systems, the GCC has taken a cautious approach, recognizing the risks of mixed signals and unintended consequences, the continued importance of political prioritization, and the important role of human and organizational arbiters.



Data-Based Decision Platform

1.5 Rotterdam in 2033

The year is 2033, and the Netherlands is three years in into a busy decade, focusing on keeping up with its ambitious climate goals and breaking free from natural gas. The country is entering the second phase of its climate law, and commitment to climate neutrality guides many political and societal developments. The Netherlands had already missed targets back in 2020 and cannot afford to fall short again. As it turns to digital solutions to deliver the necessary acceleration, its attention zooms in on Rotterdam. The city has long been known as a frontrunner in digitalization, an experimentation hub, a place where many smart city developments were showcased over the last 15 years, guided by the Roadmap Next Economy and fueled by the entrepreneurial spirit of the citizens.

Rotterdam enters 2033 as a thriving, vibrant city. While the population has not changed much in the last 15 years, a lot of shifts have occurred in the ways in which the society is arranged. The relationships between actors have changed, with shared ownership models and alternative business models empowered by digitalization dictating the new order. Gemeente Rotterdam is increasingly involved in public-private initiatives, and a huge variety of alternative smart solutions tested in the city over the last two decades created a need for firm decision making and prioritizing. In search of the ultimate variable which decides which solutions get high level support, the city turns to climate impact.

Rotterdam has become inextricably connected to the nearby municipalities, through energy infrastructure, informational flows and transportation networks. But it is not just the infrastructure that connects the cities. Smart city ideas flow effortlessly from one place to another, and Rotterdam has become a nationwide lighthouse for all things smart. The Hague, Utrecht and Eindhoven are trying out Rotterdam's smart thermal pants, and the fit is astonishing!

Rotterdam has come a long way on its path to become smart, but a new challenge of putting the lego pieces together and creating a well-functioning, well-integrated system lies ahead. Some developments were pushed back by political legacy of the times long forgotten, and only now start taking off, following overdue and much-awaited regulatory changes. While multi-source local networks provide some heating and cooling in several areas of the city, the district heating network has expanded and integrated with the cities nearby. Meanwhile, increased energy efficiency of the built environment has reduced the need for heating, and low electricity prices led to a comeback of electric heating. Integrated and optimized RES, storage and e-mobility options complement and promote each other, and have become big enough to shift the political debate, even if most electricity comes from the increasingly renewable electricity grid. Individual car use has shrunk, and public transport is almost entirely carbon free and electricity-based since 2025. Smart and interlinked measurement, management and maintenance optimize energy use in buildings in some areas, while the full potential is still to be unlocked. Smart and open data platforms enable a wide range of public services and a somewhat smaller but growing range of new business opportunities. Nonethelss, some remain reluctant to share.

1.5.1 Rotterdam's RUGGEDISED solutions, scaled up

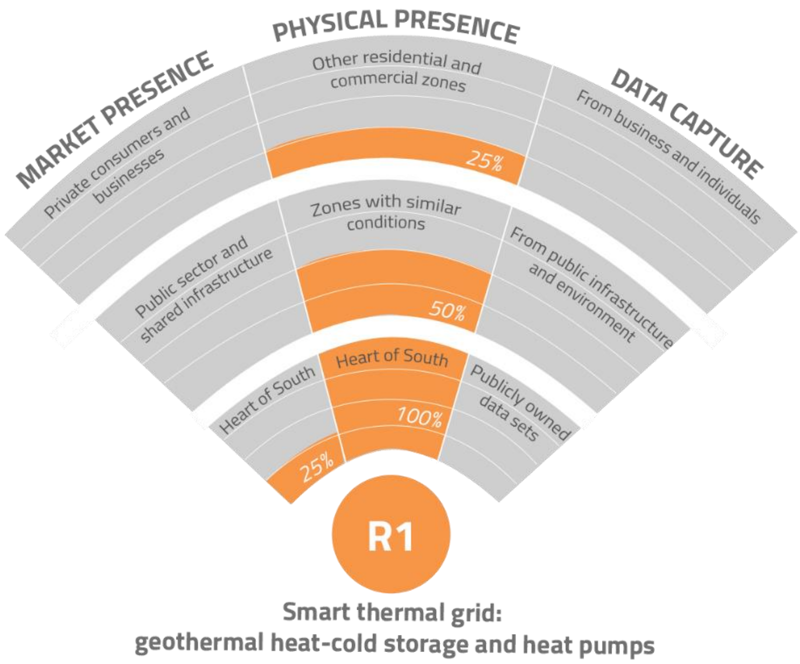
A number of smart, sustainable solutions demonstrated in Rotterdamn in the late 2010s played a significant role in 2033 – in Rotterdam and elsewhere.

1.5.1.1 Smart thermal grid (R1, R2, R3, R4, R12)

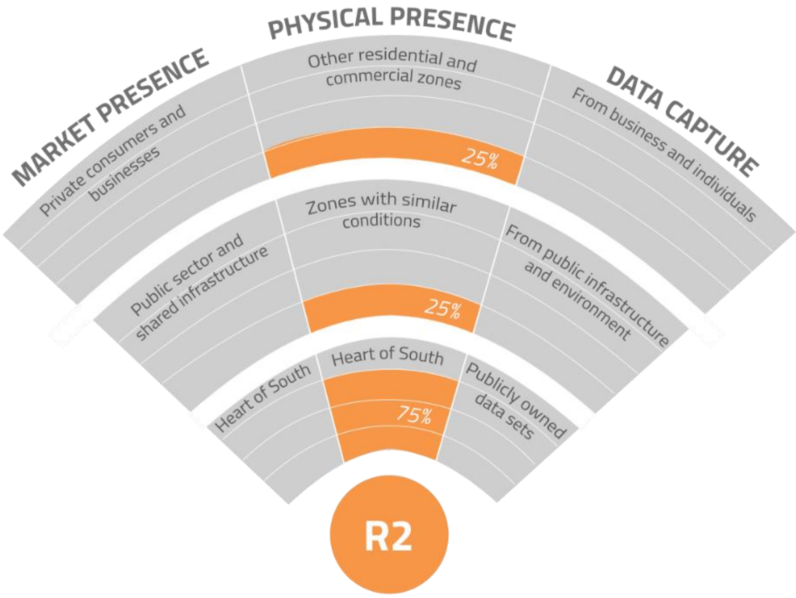
Heart of South is known nationwide for its successful demonstration of the feasibility of smart thermal grids. Following demonstrated efficiency gains, similar projects were created in half of the areas with the right geographic and infrastructural conditions. It proved harder than expected to find such areas, but Rivium-AIG, Rotterdam Central District and Feyenoord City agreed to develop their own respective grids. The success of the Heart of South crosses the city borders, and similar networks appear in Utrecht.

While the developments were thrown back some years due to requirements to connect the buildings to the district heating network, it has become a lot easier to apply for and get exemptions. The requirement is seen as a relic of the past, a cause of a lock-in and an expensive cost to bear in the context of drastically reduced heat demand. The shifting power dynamics in the heat market are palpable, with changes in regulation on the horizon.

Still, most of the heating is supplied through the district heating network, which recently expanded to include the Hague area. The decreased fuel availability due to waste prevention efforts is successfully balanced by energy efficiency efforts at the recipient buildings and by connecting new, diverse and renewable, sources, not the least deep geothermal from the Hague. At the same time, another actor is making its reappearance on the heat scene. Due to falling electricity prices, electric heating is becoming an economically viable solution that fulfills the "no more than a gas boiler" pricing rule. These are now seen as an alternative for houses where not a lot of smart solutions are applicable, such as high-rise buildings and individual houses.

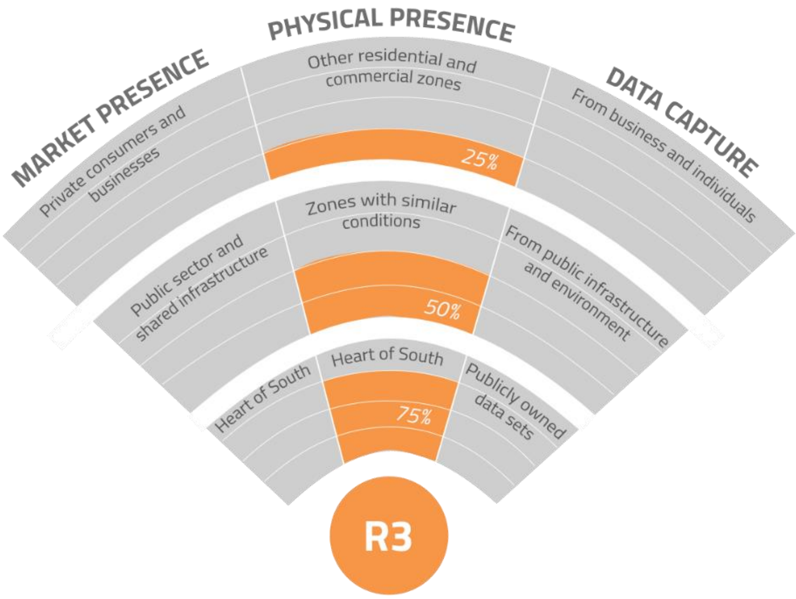


Initially introduced to compensate for the shortage of heat in local thermal grids, waste streams (R2) from most of the houses in the Heart of South and most of the surface water (R3) are now captured and transferred for seasonal storage in the local grid. However, the solutions did not take off in other areas where local heat grids were developed: a decrease in demand for heat due to energy efficiency corrected the heat-cold balance and reduced the need for additional heat sources. To minimize disturbances for the residents and to bring down the costs of construction, it was decided that waste streams will only be connected to the local grid when and where sewage replacement was taking place, which limited the number of suitable areas and appropriate time windows even further.

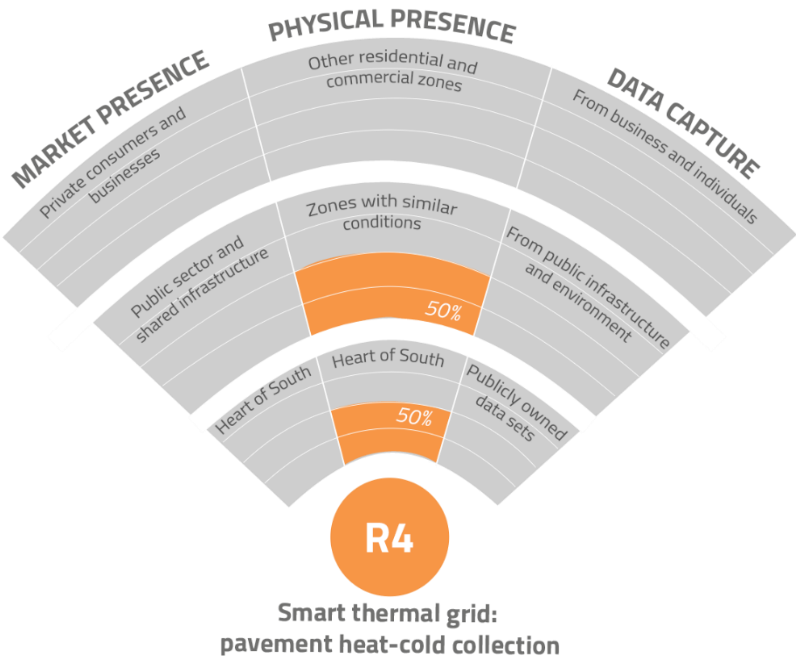


Smart thermal grid:
thermal energy from waste streams

Pavement heat-cold collection (R4) has proven a popular measure with citizens, reducing the number of accidents in winter and the need for maintenance of bus stops and sidewalks. However, the need for seasonal storage substantially limited the implementation of the solution to only half of the zones with similar conditions to the Heart of South. Alternative arrangements are being considered for other areas, following the requests and positive feedback from citizens.

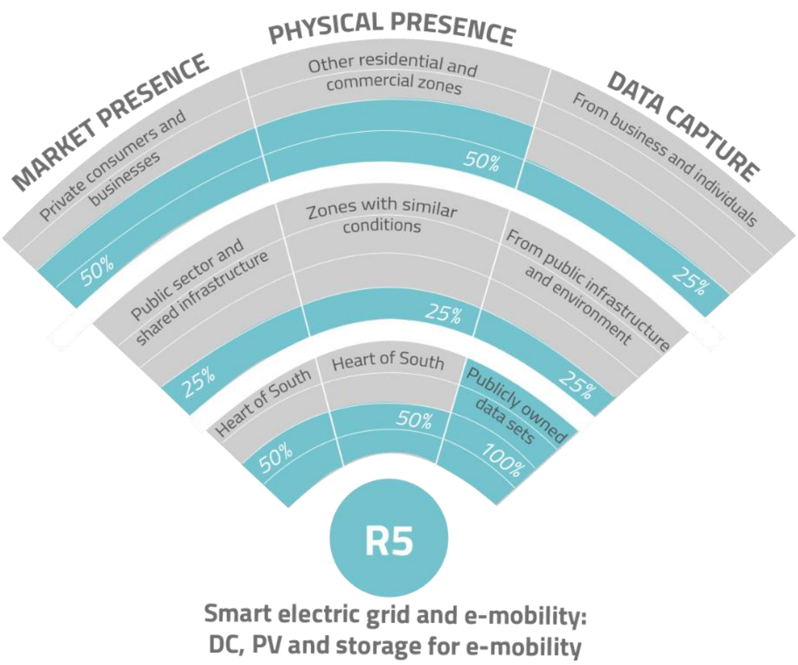


Smart thermal grid:
surface water heat-cold collection

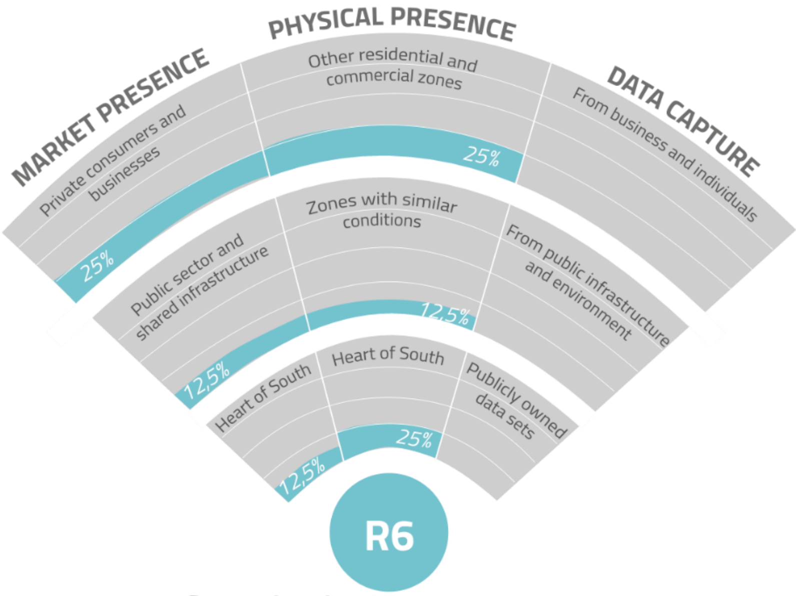


1.5.1.2 Smart electric grid and e-mobility (R5, R6, R7)

Solar based DC grids supply half of all electricity in the Heart of South. A shortage of appropriate and available space for installation limited the amount of deployment in other parts of the city. Only a quarter of all parking lots get their electricity supply through local grids, but the parking lots are half empty anyways.

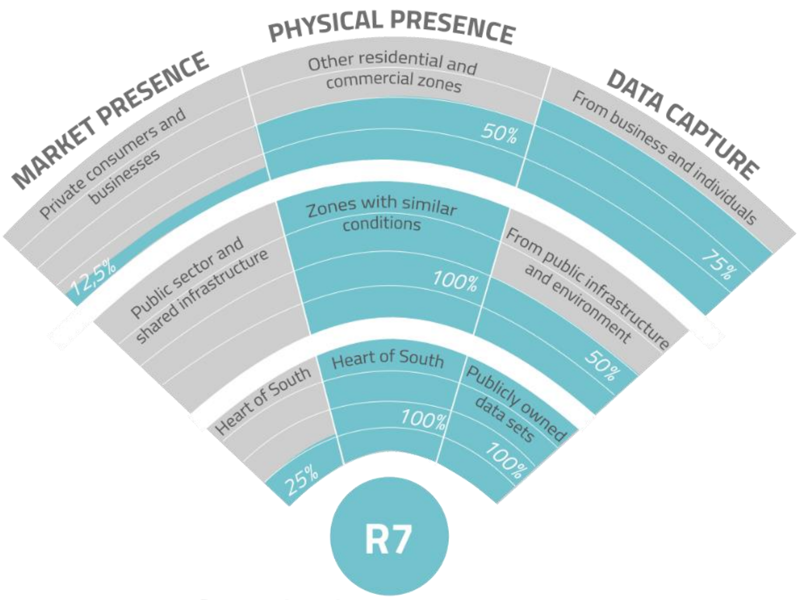


Walking down the streets, you see pedestrians rushing to their destinations, people on electric bikes rolling effortlessly, cargo bikes delivering goods, electric scooter owners dodging the crowds; you see big electric buses, small autonomous buses, and an occasional car that is now forced to share the roads with them all. You can't see it clearly as the others are blocking your vision, but you know that this car is most likely electric, and probably shared. Driven by zero emission targets, the RET bus fleet (R7) is now fully electric, receiving a part of its electricity from the local DC grids through two-way charging poles.



Smart electric grid and e-mobility:
Smart charging parking lots

The route planner was successfully optimized to take account of the constantly evolving charging infrastructure and the specificities of renewables, but the bus fleet itself has also been optimized. City buses come in various sizes, smaller ones serving less popular routes, and while all zones of the city are reachable with public transport, it only takes up a small share of the total market for mobility. Different transportation modes are being integrated into the route planner, following their increased market share. This requires increased collaboration between MaaS providers, public transport operators, shared bikes and micromobility companies and the municipality, while the city infrastructure struggles to keep up with the shift in mobility preferences.

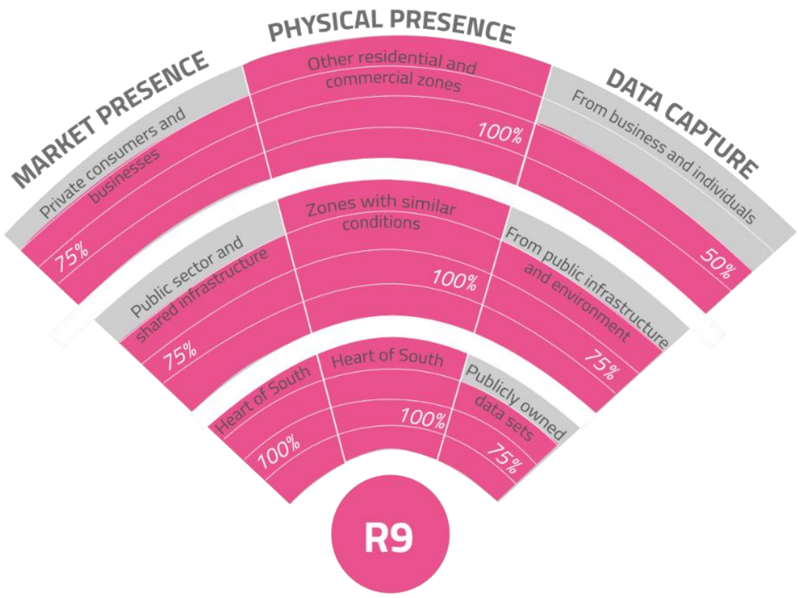


Smart electric grid and e-mobility:
E-bus optimisation

1.5.1.3 Smart data (R9, R10)

The digital twin has finally lived up to its name, transforming into an almost indistinguishable copy of the physical city. The twin covers the whole city and even more, as it exposes the underground infrastructure and visualises the information that otherwise escapes the eye. But its role is gradually shifting from predominantly a visualization tool to a decision-making tool. Gemeente Rotterdam sees the platform as a way to make sense of, and choose between, various urban development paths and alternative solutions to city challenges, and more and more sophisticated queries push the platform's data processing capacities to the limit. While the issue of data incompatibility is largely solved through open standards and broad agreements, there are still some blank spots in the model, many due to privacy concerns. A quarter of the market was lost to private alternatives: as the first versions were not running smoothly enough, and users with more sophisticated demands turned to the Big 5 for a more tailored and need-specific approach.

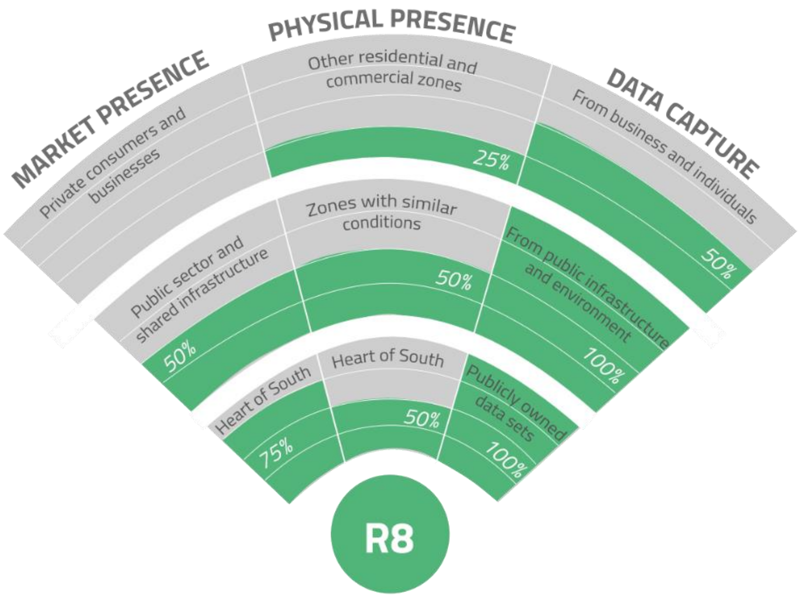
Making businesses realise the potential of the model is taking quite some time. Initial hesitations were related to shared ownership and full transparency, and the companies remain much more eager to use the data than to share their own data with the platform. From new hologramic city quests and maps, to advertising, to mobility apps, to sophisticated applications combining multiple data sets – the potential business cases have proven diverse but rather slow to emerge. The city has ambitious plans for the platform, but a hunt for data lies ahead: 50% of potentially useful data from individuals is still not captured, and 25% of data from publicly owned or controlled databases still needs to be integrated.



Smart data: 3D city operations model

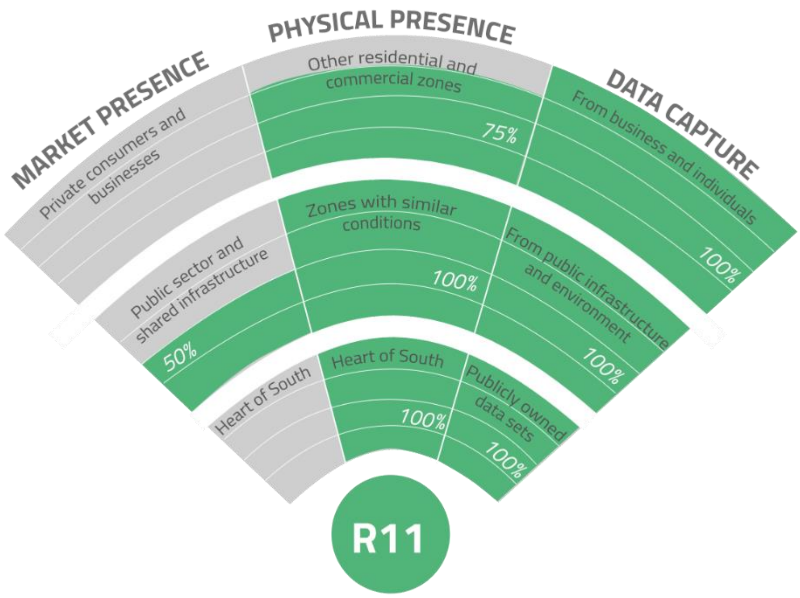
1.5.1.4 Smart services (R8, R11, R13)

Energy management systems (R8) have also faced challenges in collecting data from private building owners, while public buildings provided all the information required. Comparing buildings on energy performance had limited effects on energy behaviour, not the least due to negligible money-saving prospects, but it provides valuable information for optimising the local energy grids.



Smart services: Energy management

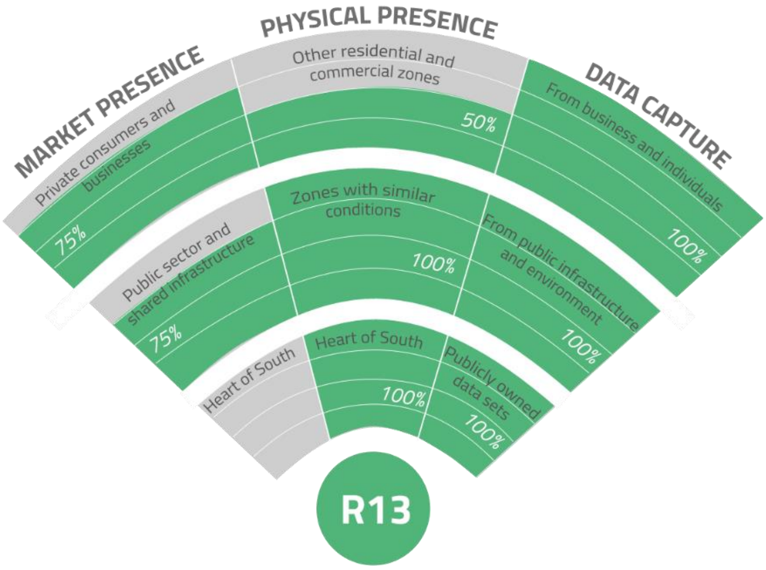
Now fully mature smart lighting projects (R11) demonstrated substantial energy savings through optimisation and even more impressive numbers on co-benefits, and all the lampposts in central Rotterdam are smart. Distant areas proved slighly less attractive, but even there 75% lampposts dim and switch off and light up based on real-time needs.



Smart services:
Efficient and intelligent street lighting

The lampposts in central Rotterdam are even smarter than that, featuring additional sensors and equipment for various uses, including weather and other alert systems, environmental sensing and flood monitoring, PV and phone charging. These even smarter lampposts act as an important information source for the city and its citizens. Already during the design stage for upscaled deployment a decade ago, it became clear that a key to an optimal system would be careful planning. Different parts needed to be assigned an appropriate location, and different functions were placed strategically to create a system of data. There are still blank spots, and inefficiencies are hard to correct due to supplier lock-in. Maintenance costs did not drop as much as expected – while automatic failure reporting contributed to cost reduction, managing the diverse hardware required additional man force. Early trials showed that not everyone liked the futuristic, gadget loaded lampposts, and design became an important criterion in choosing the suppliers.

The waste management system (R13) is undergoing huge structural changes as CO2 reduction through prevention of waste becomes the priority and the treatment volumes gradually decrease. Smart waste management solution (R13) is seen as a way to reduce the climate impact of waste collection while contributing to reducing the financial burden on the system.



Smart services: Smart waste management

In Rotterdam, about three quarters of all waste is now collected through smart routes, and the system has gradually improved to include even the most challenging waste types. Sophisticated algorithms fed with city-wide data dictate the optimal, climate-impact-minimizing routes for collection trucks, while the planning is facilitated by AI-based filling rate prediction. The collection itself is increasingly done by autonomous vehicles, which contributes to CO2 reduction, but less so to reduction in labour intensity: the need for workers remains and money is spent on re-educating truck drivers to handle autonomous waste collecting vehicles.

Meanwhile, showcase bins are being developed in the Heart of South. They come with AV friendly designs and robot assistants to fully eliminate the need for labour, and use advanced sensor technologies to measure multiple waste parameters and help decide on appropriate treatment method. Up ahead is a whole new level of integration, where the platform captures and exchanges data from all stages of waste management, and where demand-driven waste collection reflects real-time needs and capacities of different waste treatment facilities in the area.

Appendix A: List of stakeholders consulted

1.6 Umeå

1.6.1 Interviewees

Christoffer **Ainek**, Umeå municipality
Olov **Bergström**, Akademiska hus
Jörgen **Carlsson**, Umeå Energi
Kristofer **Linder**, Västerbottens läns landsting
Jakob **Odeblad**, Västerbottens läns landsting
Lisa **Redin**, Umeå university
Frida **Sandén**, Umeå municipality
Ebba **Sundström**, Umeå municipality

1.6.2 Scenario workshop attendees

Carina **Aschan**, Umeå municipality
Daniel **Bengtsson**, RISE Research Institutes of Sweden
Frida **Bergström**, Umeå municipality
Olov **Bergström**, Akademiska hus
Jesse **Fahnestock**, RISE Research Institutes of Sweden
Elisabeth **Lind**, Umeå municipality
Kristofer **Linder**, Västerbottens läns landsting
Jakob **Odeblad**, Västerbottens läns landsting
Lisa **Redin**, Umeå university
Frida **Sandén**, Umeå municipality
Ebba **Sundström**, Umeå municipality

1.7 Glasgow

1.7.1 Interviewees

Ian **Hewlett**, Siemens
Ciaran **Higgins**, Derryherk Limited
Gavin **Slater**, Glasgow City Council

1.7.2 Scenario workshop attendees

Bob **Cree**, Glasgow City Council
Robert **Davidson**, Glasgow City Council
Erica **Eneqvist**, RISE Research Institutes of Sweden
Noemi **Giupponi**, Glasgow City Council
Blair **Greenock**, Glasgow City Council
Ciaran **Higgins**, Derryherk Limited
Magnus **Johansson**, RISE Research Institutes of Sweden
Nick **Kelly**, University of Strathclyde
Laura **McCaig**, Transport Scotland
Andrew **Mouat**, Glasgow City Council
Michelle **Mundie**, Glasgow City Council
Mic **Ralph**, Glasgow City Council
Gavin **Slater**, Glasgow City Council
Emma **Thomson**, Glasgow Cithy Council

1.8 Rotterdam

1.8.1 Interviewees

Roland **van der Heijden**, City of Rotterdam
Wouter **Ijzermans**, Eneco
Wim **Kars**, City of Rotterdam
Rick **Klooster**, Future Insight
Peter **Wijnands**, City of Rotterdam

1.8.2 Scenario workshop attendees

Adriaan **Slob**, TNO
Albert **Engels**, City of Rotterdam
André **Houtepen**, City of Rotterdam
Christian **Veldhuis**, City of Rotterdam
Jasper **Feuth**, Eneco
Jilian **Benders**, City of Rotterdam
Magnus **Johansson**, RISE Research Institutes of Sweden
Marcel **van Oosterhout**, Erasmus Universiy
Peter **Wijnands**, City of Rotterdam
Roald **Suurs**, TNO
Rob **Schnepper**, City of Rotterdam
Roland **van der Heijden**, City of Rotterdam
Roland **van Rooyen**, City of Rotterdam
Theo **Konijnendijk**, RET
Wim **Kars**, City of Rotterdam
Virgil **Grot**, RET
Wouter **van Rooijen**, City of Rotterdam

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