RUGGEDISED

Designing smart, resilient cities for all

Vol. 2

Implementation report Umeå

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Umeå is a fast growing city with its population expected to pass 200 000 by 2050.

Source: City of Umeå

1. Executive summary

Smart city thinking is at the core of the City of Umeå's overall vision for urban development, which builds on the city's commitment to having a climate neutral energy system by 2030. As part of RUGGEDISED, Umeå is focusing on implementing nine solutions in the University District situated to the east of the city centre, which is the largest workplace in northern Sweden with more than 50 000 employees. Umeå is growing quickly: the average age of the nearly 123 000 residents is 38 and the City aims to pass the 200 000 inhabitants mark before 2050.

The need to prepare for future demands has been one of a number of drivers pushing the City's commitment toward sustainable growth, and subsequent involvement in RUGGEDISED, forward. Other drivers include:

- environmentally aware citizens who put pressure on the city to be progressive;
- active participation in international networks like the Union of Baltic cities, URBACT, CIVITAS, ICLEI and many more;
- involvement in national and international projects.

Through the RUGGEDISED project, Umeå is implementing nine smart city solutions (U1-9) to ensure the City achieves two, often diverging, goals: population growth and a lessening of environmental impact. The solutions are currently in different phases of implementation, with results for some solutions already demonstrating energy reductions of 23 percent and better management of peak load periods.

Often when trying to optimise energy use, the general approach has focused on supply chains and building logistics. Umeå has put a strong focus on its end users, namely citizens who have been ranked - as part of the 2014 European Smart City Benchmarking by the Vienna University of Technology - as some of the most active and environmentally aware citizens in Europe. But, there is still room for improvement! And the technology that is implemented is only as effective as its users. Therefore, a key aim is to encourage behavioural change, through gamification (U4A), as part of enabling a broader social shift in the adoption of more sustainable habits for all aspects of life.

Smart building management (U4B), which is connected to an energy demand management system (U9), of different buildings in the University District, for which over 500 additional sensors have been installed, has been used to gain a better understanding of power consumption and to lessen the level of unnecessary energy use. On a district level, Umeå has developed different business models (U1, U3) to enable buildings to share excess renewable energy and has implemented a system that makes it possible for buildings to store excess heat produced in the wider district. Work here has been useful in developing a more holistic view of the often complex business landscape of energy supply systems – local and distributed – and has provided the opportunity to pinpoint bottlenecks, and find ways of mitigating them.

To make sure that traffic jams and lower air quality do not follow an increase in population, Umeå has implemented an innovative approach to parking (U7) for the more central parts of the city, making it attractive for employers to support sustainable mobility. This, together with the installation of photovoltaics to power electric vehicles (U6) without adding burden to the overall energy system and a new climate-smart bus stop (U5), are approaches that have been tested in Umeå and encourage better urban mobility. These approaches also have a high potential for replication in other cities.

While data is a universal language, translating it into local climate action remains a challenge. Umeå has developed an open-data decision platform (U8) allowing city officials, outside experts and citizens to access, and visualise, different data from the City. To achieve a more sustainable, liveable city, Umeå has taken a number of related actions, including conducting market research for an out-of-the-box solution, considering a process for presenting data consistently, making sure the portal is sufficiently populated and ensuring developers of the future are aware of this data source.

2. Progress summary visualization table

Progress summary visualization table	U1/U3	U2	U4a	U4b	U5	U6	U7	U8	U9
Business model development	✓	✓	▮▮▯	✓		✓	✓	N/A	N/A
Business model feasibility proven	🏆	🏆	🕒	🏆		🏆	🏆	N/A	N/A
Project development to prove viability and impact	N/A	N/A	N/A	✓	✓	✓	✓	✓	✓
Project investment ready or bankable	N/A	N/A	N/A	🏆	🏆	🏆	🏆	🏆	🏆
Partners' Cooperation agreements	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cooperation agreements signed	🏆	N/A	🏆	🏆	🏆	🏆	🏆	🏆	🏆
Project implementation plan development	▮▮▯	✓	✓	✓	✓	✓	N/A	✓	✓
Project plan approved	🕒	🏆	🏆	🏆	🏆	🏆	N/A	🏆	🏆
Approval/permit procedures	N/A	N/A	N/A	✓	✓	✓	N/A	N/A	✓
All permissions and notifications procured	N/A	N/A	N/A	🏆	🏆	🏆	N/A	N/A	🏆
Procurement process	✓	✓	✓	✓	✓	✓	N/A	✓	✓
Key components procured	N/A	N/A	N/A	🏆	🏆	🏆	N/A	🏆	🏆
Project implementation	✓	✓	▮▮▯	▮▮▯	✓	▮▮▯	✓	▮▮▯	✓
Project commissioned	🏆	🏆	🕒	N/A	🏆	N/A	🏆	🕒	🏆
Monitoring phase	▮▮▯	▮▮▯	▮▮▯	▮▮▯	▮▮▯	▮▮▯	✓	▮▮▯	▮▮▯
Monitoring completed	🕒	🕒	🕒	🕒	🕒	🕒	🏆	🏆	🕒
Upscaling phase	▮▮▯	▮▮▯	N/A	N/A	N/A	N/A	N/A	▮▮▯	✓
Plans for upscaling			N/A	N/A	N/A	N/A	N/A	🏆	🏆
Replication phase	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	✓
Replication planned	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	🏆

▮▮▯ In progress ✓ Done 🏆 Go decision 🕒 Pending **N/A** Not applicable

3. Umeå and RUGGEDISED

The current period in which we live is characterised by rapid technological development, the strong globalisation of (social and economic) activities and the need to protect our living environment, while ensuring social stability. As part of the European-funded smart city project RUGGEDISED, three Lighthouse cities - Rotterdam, Umeå, and Glasgow - together with a number of partners from academic, business and consultancy backgrounds, will develop and test ideas to exploit and explore the opportunities that smart solutions offer sustainable urban development.

RUGGEDISED's three overarching aims are:

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

2. Reducing the environmental impact of activities by achieving a significant reduction of CO_2 emissions, a major increase in the investment and usage of renewable energy sources and an increase in the deployment of electric vehicles, and;

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

Smart city thinking is at the core of the City of Umeå's overall vision for continued social, economic and environmentally sustainable growth, outlined annually by the City Council. Umeå is growing fast and in order to ensure sustainable growth, the City is seeking to better understand some of the known economic, social and environmental challenges faced by larger cities and how to address them before they occur in Umeå. Building on the city's commitment to a climate neutral energy system by 2030, coupled with rapid urban growth, Umeå focuses on 'smart innovation' to curb energy use as part of city planning.

In RUGGEDISED, Umeå focuses on an Innovation District situated immediately to the east of the city centre as part of the University area. The need to prepare for the future demands of the energy market, including changing consumption patterns and changes in legislation surrounding power distribution, has been one of the drivers outlined in the joint strategy which was developed by partners in the University City area.

The University City area is the largest workplace in northern Sweden and has both local, regional, national and international relevance. More than 50 000 people enter the area daily, but only around 3 000 live in the area. Thus, there is a mobility challenge. Reducing transport related CO_2 emissions is an important goal for the city. The innovation area of the University City is characterised by a young, student population and makes the area an interesting district for new smart solutions and business models that are more dependent on sustainable mobility options.

The RUGGEDISED Project

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

Source: Umeå University / Mattias Petersson

Implementation drivers to embark on RUGGEDISED

Umeå is one of the fastest growing cities in Europe, and it places a strong emphasis on research and development. Businesses and citizens are famous for their active involvement in the City's sustainable development as confirmed by the 2014 European Smart City Benchmarking from the Vienna University of Technology, which ranked Umeå's citizens as Europe's most environmentally aware. The citizens of Umeå put pressure on the City to be progressive, bold and to put forward new green solutions.

The City of Umeå is also very active in several international networks and currently holds political positions as first vice-President for the Union of Baltic Cities, in addition to being a member of the CIVITAS Political Advisory Committee. It has been involved in and managed several national and international projects including: Green Citizens of Europe (Life Plus) and Sustainable Ålidhem, the Swedish Delegation for Sustainable Cities. It was also recognised by the EU Sustainable Energy Awards, winning the 'Living' category in 2013. Since 2008, Umeå has been a signatory of the Aalborg Commitments, which underpin the six strategies driving Umeå's urban development.

Umeå's smart city vision

"A world-class neighbourhood for education, research, health care and business development; an attractive city that lives around the clock with a mix of activities, housing, services and trading environments that invite movement in everyday life and that can contribute to better health.
That is Umeå's smart city vision."

Umeå's smart city vision

Various plans shape Umeå's smart city vision and ambitions, including the Sustainable Energy Action Plan (SEAP), a City Master Plan and an in-depth Master Plan for the campus area (a part of the City Master Plan). The six development strategies, introduced below, are based on the Aalborg Commitments and the Umeå City Council's objective of sustainably growing the city's population to 200 000 inhabitants by 2050 (from 123 000 today).

1. The 5-kilometre city – The dense city! Growth should be concentrated within a 5 kilometre radius starting from the city centre and the University area

2. More city! – As a complementary force, the city should be merged into a more coherent urban landscape

3. Create high density in new districts, including new adjoining blocks that strengthen and develop services and urban life

4. Growth in public transport corridors and conversion of traffic throughways, including new dense block development planned alongside alleys benefitting public transport

5. Invest in public spaces and parks! As part of the dense city, public spaces should be attractive, safe and full of experiences, with room for recreation and greenery

6. Everybody shall participate! All planning must be carried out openly, democratically and in consideration of gender equality

Similarly, the in-depth University Area Master Plan outlines a district with education, research, healthcare and area-related business development at the highest international level, where the following objectives are emphasised:

- City-life promoting activities at street level with entrances along the main passages/corridors;
- Prioritised passages for education and healthcare, along with research-related business development;
- Clear urban structure with mixed use: business, housing, service and retail;
- Urban block structure in a coherent street network – improved orientation around main entrances to the regional hospital.

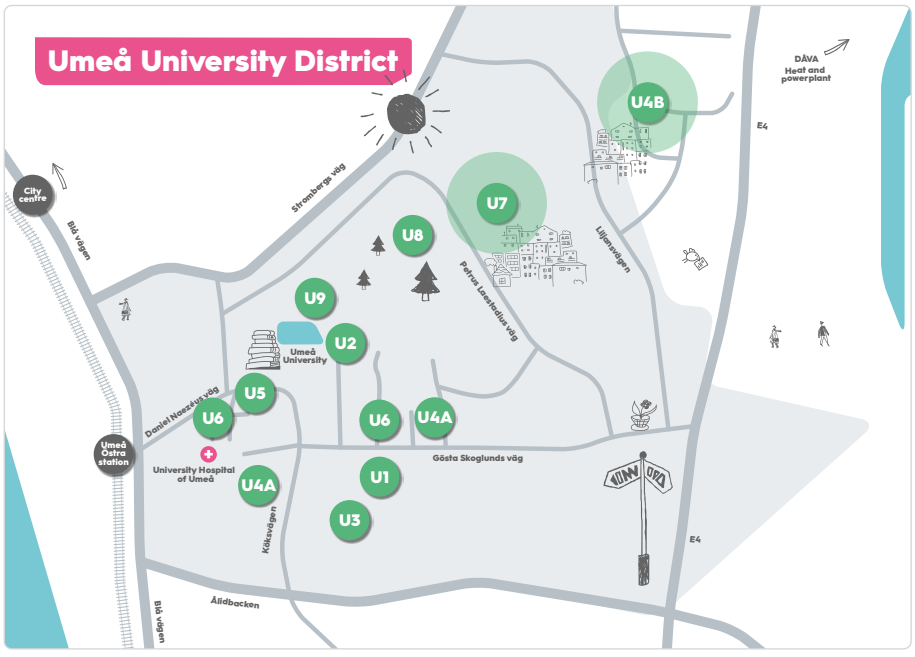


Figure 1: Simple overview of solutions.

4. RUGGEDISED in Umeå

The city of Umeå is constantly growing and is expected to pass the 200 000 inhabitants mark by 2050. Never have so many new homes been built in the city. Umeå's goals to have 100% renewable energy and a fossil free transport system by 2030, make innovation projects like RUGGEDISED vital for the city to continue growing without compromising its sustainability goals.

To engage in the project, both the city planning and mobility departments had to work together, as well as related energy, mobility, housing and real estate companies. By engaging in the RUGGEDISED project partnership, the cooperation between partners was formalised. Over time, the partnership has become permanent and many other collaborative projects and business deals have been developed. Some partners have their main interest in the University innovation area, but most partners consider the whole city their target area. This has resulted in similar, extended smart city collaborations with new actors.

The positive results achieved by the RUGGEDISED project, in part due to close cooperation between partners, have also attracted a substantial part of the large estate and housing companies in Umeå to engage with the City as well as energy and mobility companies in the planning of new large housing areas.

COVID-19 Impact

The pandemic has not had any severe effects on the implementation of RUGGEDISED in Umeå. Most of the solutions' implementations went according to schedule, meaning that the technical implementations were completed before the start of the pandemic. However, the results of some implementations have been more difficult to evaluate since there are less people in the University area as a result of COVID-19. Another thing that affected the project, and still is affecting it, is the fact that Umeå was not able to host large inaugurations or to celebrate its achievements. Communication is therefore significantly impacted and it has been difficult to share the results with inhabitants.

In some cases, we have been given new insights because of the pandemic and subsequent lock down. For example, solution U9, energy demand side management, has shown us that there are further possibilities to reduce the facility areas than expected, since offices and rooms have been used less as a result of distance working during the pandemic. A new strategy for increasing the efficiency of facility usage has also been developed and the implementation has begun.

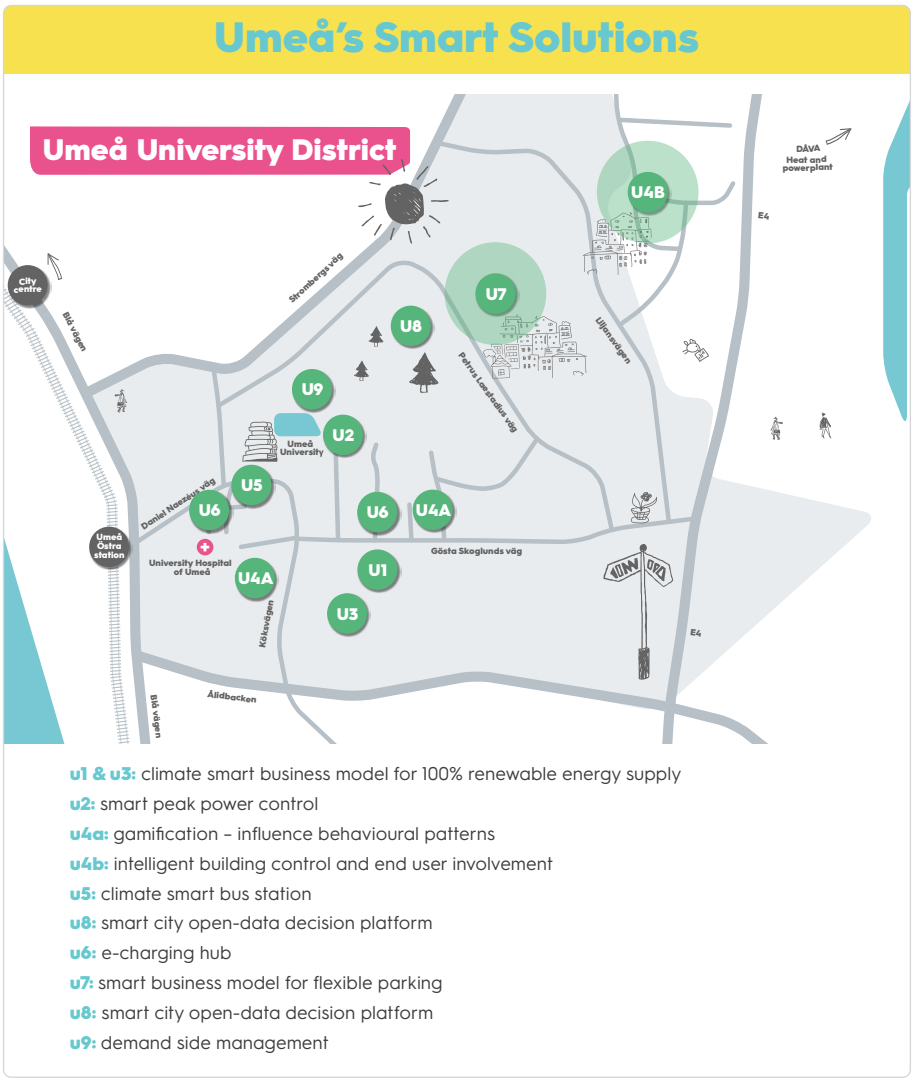
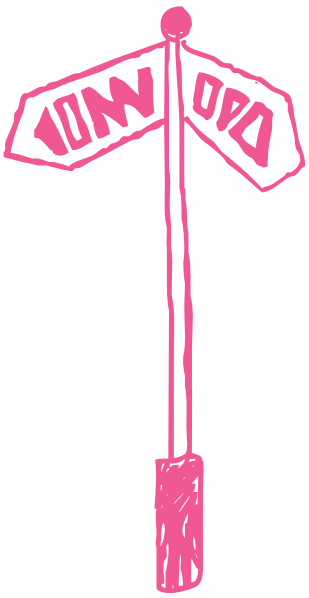


Figure 2: Full overview of solutions.



5: Description of Smart Solutions

Solution U1 & U3: Climate smart business model for 100% renewable energy supply

General description: The purpose of the U1 and U3 solutions is to develop a new business model to make it possible to share excess renewable energy between stakeholders in a value chain and ensure better usage of geothermal storage. The overarching goal is to help the stakeholders reduce their climate impact and lower the costs of energy. Three different business models were tested and applied to nine ways of optimising energy use in the Innovation Area and evaluated to show how value creation might occur in the different scenarios.

Figure 3 shows the technical model describing the energy supply infrastructure of the testbed area. The project has analysed the demand and supply data of the different buildings and production facilities of the area.

The model was designed in VBA (Visual Basic for Applications) Excel, using data from 2017 of all production units' local and distributed energy. A scorecard using emission factors and the costs of different fuels and investments, was created to assess the costs and benefits of different scenarios.

Expected impact: The business models were expected to have three impacts: Firstly, through the extensive energy analysis exploration, they would help set the baseline for optimal steps towards realising a 100% renewable energy supply between stakeholders. Secondly, the solutions would introduce a new value proposition to the current business model and provide insight into how the transformation process is best done. Thirdly, U1 and U3 should offer conclusions and an agreement of suitable steps forward.

Current implementation stage: The solutions have now completed the final stage of implementation: to conclude all the energy analyses, business model innovations and cash flow analyses. The project team has reached a consensus via a letter of understanding, which shows a pathway of steps forward.

Results: Monitoring in progress.

Innovation: The in-depth energy analyses, combined with business model innovation, have given a holistic view of the often complex business landscape of energy supply systems – local and distributed – and they have given Umeå Energi AB and the Västerbotten Region – working jointly on the solution – the opportunity to pinpoint bottlenecks and find ways of mitigating them.

Connection to other smart solutions: The business model/-s developed through U1 and U3 effectively support the practical application of the U2 technical solution 'Smart peak power control,' which aims to reduce peak loads and subsequently CO_2 emissions. The Region and the energy utility is connecting the solutions on a holistic level in order to find the value proposition, which promotes synergies between solutions.

Connection to existing urban system and citizens/users: U1 and U3 are innovations based on the existing energy systems of district heating and cooling, heat pumps and geothermal storages. By integrating software with traditional energy systems, the solutions is able to help reduce the climate impact of the energy systems.

Upscaling plans: The project team is looking into different ways to implement the business models in the University City area. One possible pathway is to test the different market components in an actual trial setup. The project team is currently having a dialogue regarding this proposal and aims to find an understanding in the near future. Right now it is necessary to confirm the findings via a physical testbed.

Replication Assessment: The results of this solution show potential for the establishment of a collective business model for energy sharing between project partners. Given the interesting results of the solution, it could be valuable to test similar approaches in other cities and energy systems.

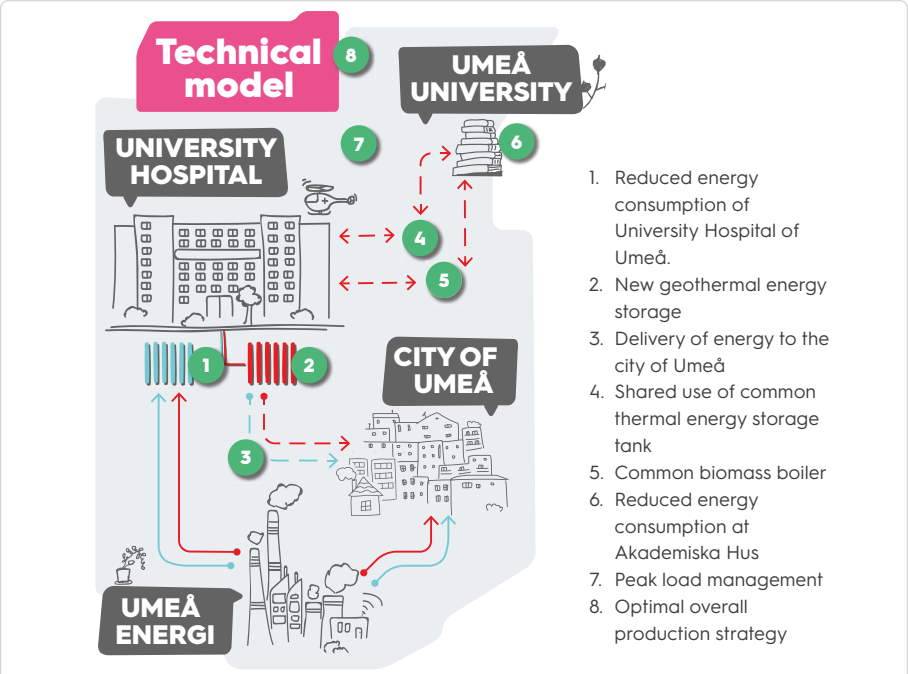


Figure 3. Schematic system hook-up (model).

Solution U2: Smart peak power control of district heating

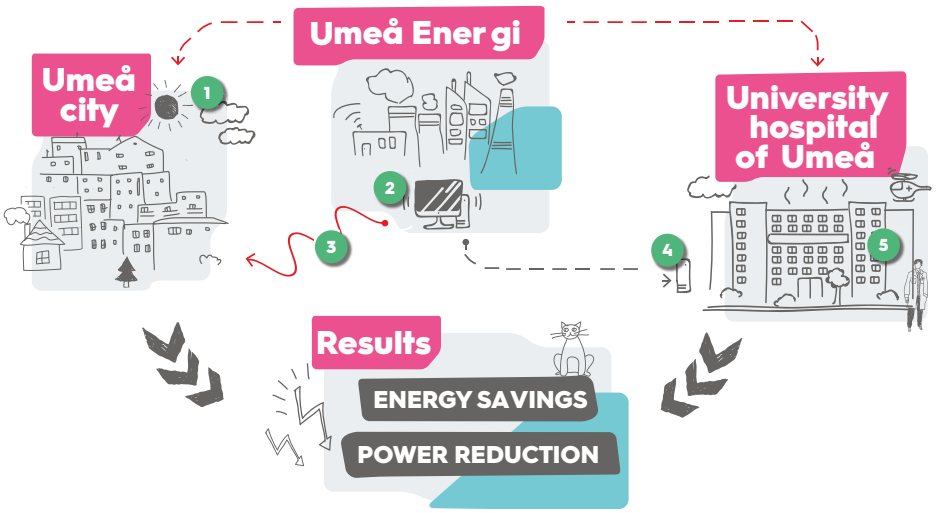


Figure 4. Display of system hook-up for space heating.

General description: The solution is based on an automated peak load management system which uses buildings as thermal energy storage hubs, so that stored energy can be used at peak periods when the need for energy is at its highest. Through this approach, it becomes possible to even out peak loads impacting district heating and to reduce the use of fossil fuels in order to secure a consistent heat supply throughout the city.

All buildings have a thermal mass that can be used to store energy. Heavy buildings (e.g. concrete) work better than light buildings (e.g. wood) for this purpose. It is feasible to install a smart control unit that assesses both outdoor and indoor temperatures in most existing systems (see Figure 5). The system analyses weather data and predicts the coming heat load so that it can constantly optimise the building's energy demands, while keeping the indoor temperatures in check. The benefits of this system are twofold – it saves energy for the property owners and reduces the peak loads of the district heating grids.

Expected impact: Installation of the peak load management system was expected to save up to 10 percent and shave peaks with15-50 percent. In order to make an impact, it would be preferable to scale the technology up and install units in a larger number of buildings. The aggregated benefit would be the possibility to mitigate peak loads on a city level. This could lead to less use of peak load boilers, which run on fossil fuels, and could consequently reduce the negative climate impact of the production of district heating.

Concluded implementation: The smart peak power controls were installed in a small number of buildings in Umeå. The buildings included in RUGGEDISED are a health centre and an office building. The health centre is used almost constantly and the office only during the daytime. Alongside these buildings, apartment blocks were added to increase the peak load reduction capacity of the tests. Everything works fine and can easily be scaled up if needed. Discussions are currently being held with project partners on the potential upscaling of the technology.

Innovation: The innovation here is to use buildings as a means of virtual energy storage. All buildings have a thermal mass, which is bigger for heavier buildings like concrete or brick buildings. This means that the heating supply of a building can be turned down for a while without the indoor temperature dropping noticeably; a maximum of ½ a degree lower saves a lot of energy, but inhabitants will not notice the slight change in temperature. This innovation means energy can be stored when demand is low and used when demand is high.

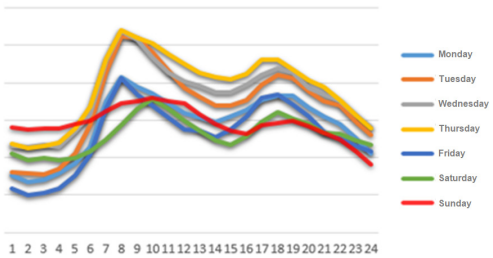


Figure 5. Heat load over different weekdays in Umeå.

Connection to other smart solutions: The use of weather forecasts in combination with heat buffering in building constructions, along with peak power controls, is smart.

Connection to existing urban system and citizens/users: By using buildings as thermal energy storage hubs, in the same way hot water storage tanks are currently used, district heating providers can avoid using peak load units, which helps to protect the environment and save money.

Results: The peak load management system has proved to save up to 8% of energy and to shave peaks with up to 21% in peak heat power usage. This system thus proves successful in reducing both energy and climate impact, whilst being cost effective since its simplistic hardware and use of AI and Machine learning improves system efficiency. The 8% in energy savings is an average for all building complexes alongside a peak load reduction potential of approximately 23% over a period of two hours. The peak load reduction occurs when the outside temperature is between -5°C to +5°C. The tests, which were run over 218 hours, resulted in a reduction of 946 kilograms of CO_2 equivalent emissions for the building complexes.

Conclusions:

- Energy savings are on average 7.85%, compared to the baseline, for the test periods. (The baseline was calculated using the energy signature method with a normal year correction.)
- The results vary significantly due to very different weather conditions found in different testing periods and as a result of the different thermal flexibility of building complexes.
- When peak heat shaving (reduction) takes place in the three building complexes simultaneously, the heat supply (peak load) can be decreased by up to 23% for a two to six-hour duration, with outdoor temperatures between -5 to +5 °C. (See table below)

Upscaling plans: The project team views these test results as quite promising, enough so to take further steps to implement similar solutions throughout the whole of Umeå's district heating systems. This solution is an effective way to implement the collective business models found in U1 and U3, in the sense that it shows a way to exploit the synergies between the building complexes, distribution network and production plants.

Replication Assessment: The solution could be of value for most heating networks and therefore of great value to promote around the European Union as a whole.

Shaved (kWh/h) [2]	Unshaved (kWh/h) [3]	Energy Reduction (kWh/ %)	CO_2-eqv reduction (kg) [1]	Annual Cost (€ per annum) [4]	CO_2eqv-reduction/ Euro (kg/ €)	Outdoor temp (°C) [5]
381,6	496,8	19 283 / 23	946	1008	0,94	- 5,7

[1] Air Emission Factors: Source: Calculated using the Swedish Greenhouse Gas inventories for 1990-2018 years' emissions to the UNFCCC

[2] Y= (-15,66* -5,7)+292,43 Mean of the test period 218 hours of load shaving

[3] Y= (-16,736* -5,7)+401,44 Mean of the test period 218 hours of load shaving

[4] Annuity calculation; Investment total 10k€, discount rate 8%, calculation period 3years, residual value 0

[5] AVE ODT Average outdoor temperature of test period

Table 1: Results of peak load management system.

Source: Umeå Kommun / Fredrik Larsson

Solution U4a: Gamification – influence behavioural patterns

General description: Often when trying to optimise energy use, the general approach focuses on supply chains and buildings. This solution was different and aimed to involve building tenants to encourage more sustainable behaviour toward energy usage and other parts of day-to-day life.

The idea was to use gamification methods to encourage tenants to alter their habits and behaviour. Through an app called The Green Coach, produced as part of the RUGGEDISED project, participants were provided with information designed to inspire them to rethink their behaviour, this included:

- providing challenges to encourage them toward particular actions;
- enabling continuous feedback regarding the results of their actions;
- holding group events to engage a larger number of participants, thus generating a bigger combined effect and a sense of accomplishment within the community.

At the start of the annual testing period, a baseline of consumption data (electricity and heating) was extracted for the selected building. The test group was then introduced to the app and provided with a package used to manage the control of their devices, lighting and heating patterns. During the test period, the app served to influence the sustainability behaviour and habits of the test group while collecting the corresponding consumption data for comparison and analysis. In addition, user interviews and feedback sessions were conducted regularly with the test group throughout the period. The test period was managed in collaboration with representatives from the real estate company responsible for the selected building.

Expected impact: The expectation was to see a change in behaviour and habits concerning sustainability and energy use. An additional aim was to increase awareness of the impact that one individual can have on energy use and CO_2 emissions by making small adjustments in their behaviour. As a long-term consequence, the hope was that this would result in reduced costs for both tenants and real estate companies, as well as reductions in CO_2 emissions.

Current implementation stage: A mock-up was first constructed at the end of 2018 and tested on external users. Results from this initial test were fed into the construction of the prototype as baseline requirements. The prototype was built and tested on a group of users during the summer months of 2019. Feedback and findings, resulting from the test were then compiled and used to introduce the full application to users in 2021.

Innovation: It is quite common for projects centred around energy optimisation to mainly focus on technical solutions covering supply chains and the actual buildings. In this case, the project aimed to study whether energy use can be lowered by encouraging behavioural change in the tenants through gamification and involvement in local events. Taking a broader, more holistic approach towards sustainability rather than just focusing on one element in isolation, like energy use, is intended to result in a broader social shift in the adoption of more sustainable habits for all aspects of life. Due to a low hit rate of tenants (see above) the project team have readdressed the scope of the solution to look more into the social aspects and the respondents' actual attitudes and behaviour during the different test campaigns.

Connection to other smart solutions: There was no direct connection to other smart solutions.

Connection to existing urban system and citizens/users: The application was not intended to be directly connected to other urban systems. However, it could have had an indirect impact on the way citizens engage with a range of different systems through the anticipated shift toward a more sustainable way of living.

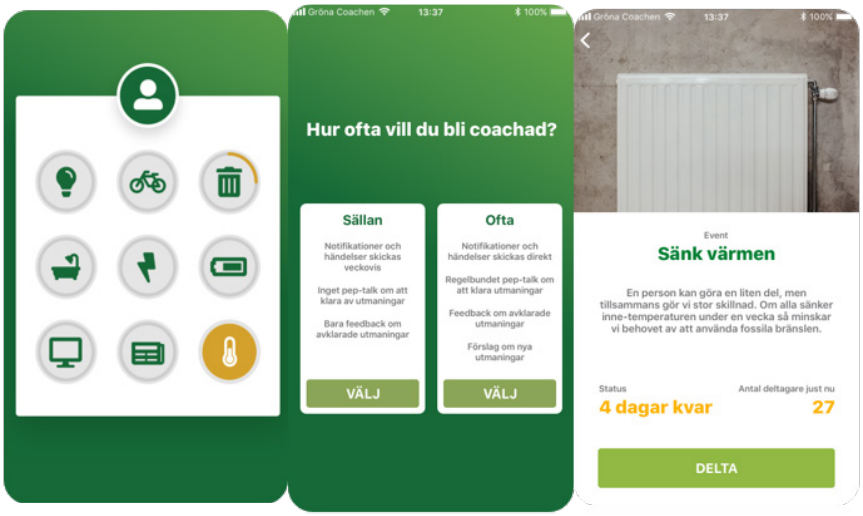


Figure 6: Umeå Energi's app.

Results: The finished application was tested over a year, using tenants of a building provided by the real estate company. However, the participation rate was unfortunately only 13%; a lot less than anticipated and hoped for. Quarterly surveys and user interviews still went ahead and focused on reviewing user activity and feedback during the test period.

The results show that it is possible to make a slight impact on tenants' sustainability habits and behaviour. Whether this perceived impact actually led to any energy savings is impossible to detect because the impact was too small, and not time stamped and therefore not detectable in the building's energy consumption data.

During the course of the project, it also became apparent that in the "noise" of today's society with many competing applications, it is very difficult to attract and maintain the attention of the user community. To be successful over time, it is crucial to actively manage campaigns to attract and maintain user interest. Change in behaviour does not come overnight, it is a process that takes time and requires continued engagement. Read a full report on the solution on the **RUGGEDISED website**.

Upscaling plans: It is quite expensive to develop features and campaigns that are of low commercial value. The decision was therefore made to terminate the application after the test run period.

Replication Assessment: There are no specific replication plans for this solution. For general replication of the concept, cutting through the "noise" of today's society is a challenge that will have to be overcome.

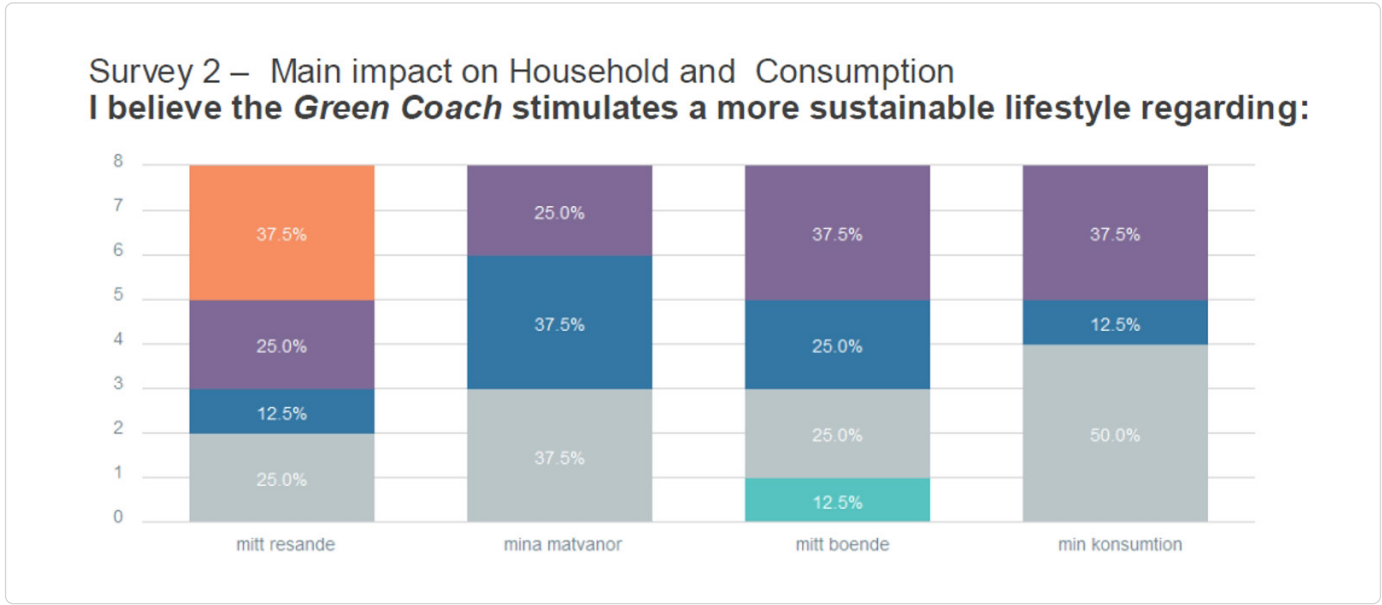


Figure 7: Survey results of the Gamification work in Umea.

Source: Umeå Kommun / Samuel Pettersson

Solution U4b: Intelligent building control and end user involvement

General description: Akademiska Hus AB, which owns and operates university and college buildings for the Swedish State, will install automatic smart control equipment to control air flow, room climate and presence-activated lighting in 130 offices at the University area in Umeå. The solution is a major energy project in one of the large lab houses, the Physiology House, and includes both offices and laboratories where ventilation is in operation 24 hours a day. The offices will be connected to a monitoring system where settings can be managed and the status reported and stored. The idea is that the air flow and lighting adjustments depend on the degree of occupancy – both current and expected – in the rooms. The occupancy rate will be the decisive factor for the total cooling effect and the heating power needed to maintain the desired climate.

The owner of the hospital in Umeå, VCC, is also installing automatic smart control equipment in office areas. In one place, the system is built for evaluation and as a testbed for personnel in order to optimise it further and to learn how to connect it to other smart systems in the best way.

Expected impact: A smart system that regulates air flow, temperature and lighting, based on the presence and number of people in a given room, has been installed and was expected to lead to a reduction in heating and electricity demand. Moreover, the rooms were connected to a monitoring system which enabled better control of the overall system. The technical solution which is partly financed through the RUGGEDISED project is a part of a large package of measures in a large complex building at Campus Umeå. There are several ongoing projects in the building which affects means specific numbers for the part of the solution that is U4B are difficult to quantify.

Current implementation stage: At the moment, the installation of the system complete. Sound absorbing ceilings have been installed to reduce noise from the installations. The installation of the solution was ongoing until October 2019, at which time the final inspection was held.

Innovation: Within the university area there are already several buildings that use smart control for air volume, but this solution integrates both the lighting system and indoor climate to ensure climate control and energy saving. The plan for the hospital is also to investigate how this solution works best with other systems and to learn the best way to operate it. Innovation-wise, installing the equipment is one challenge; another is to make it reach the highest targets in terms of energy usage.

Connection to other smart solutions: This solution contributes to the conditions for U2 'Peak load management' and U9 'Demand side management.'

Connection to existing urban system and citizens/users: Installing this solution enables use of the supply system in a smarter way.

Results: The monitoring of this solution is ongoing. In the beginning of the monitoring period, there were some problems with the resolution of the energy meters which has affected the monitoring of the solution. The energy meters have since been replaced and improved upon, and a clear trend that shows energy savings is expected, which will be made available in the final implementation report in October 2022.

Upscaling plans: Demand-controlled ventilation and lighting is a standard solution for new constructions, which will continue to be used in Sweden. However, it has been proven that it is difficult to obtain profitability when installing demand-controlled ventilation and lighting in existing systems in building complexes. In connection with more extensive renovations for our tenants, we aim to bring together this system and profitability.

Replication assessment: Due to strict requirements regarding ventilation in Sweden, this solution would be relatively simple and useful to replicate for future construction. In the rest of the Europe, the requirements are different which means that the additional cost of this solution will probably be too high relative to a simpler solution. On the other hand, energy is in many cases more expensive. To be able to replicate this solution in an existing building, a balanced ventilation system with supply and exhaust airflow must exist.

Figure 8: Smart system components: The intelligent building control includes sensors, lighting, and the chilled beam which allows control temperature and ventilation.

Figure 9: Smart system components. Source: City of Umeå.

Solution U5: Climate smart bus station

General description: The climate smart bus station is a new type of bus stop that is expected - with its innovative design in which technology, people and the environment interact with one another - to help reduce the city's environmental impact and its carbon dioxide emissions. It is also a symbol of the smart University area. The bus station serves both electric and fossil fuel buses. Procurement was carried out as a design-and-build contract.

Expected impact: With its futuristic and unique design, the bus station was established to showcase public transport as a modern mode of transport for a smart city. The design aims to give passengers the opportunity to 'rest and reflect' while waiting for the bus. The design is also supposed to contribute to a reduction in boarding time and thus, to a small extent, a reduction in CO_2 emissions.

Current implementation stage: The climate smart bus station is implemented and in service. Innovations include:

- Hanging pods to create a micro-climate for the passengers, which can be turned in any direction by the wind or by choice of the traveller. The pods are placed in such a way that the bus station, if necessary, can be ploughed with a snowplough.
- The meditative light and soundscape is connected to the buses' real-time GPS-system. The GPS-system updates its data every five seconds. Each bus route has its own colour and sound, and data for incoming buses is displayed on a screen in the bus routes' unique colours. The light and sound make the station more accessible for citizens with a visual impairment or hearing loss. Children who cannot read can learn the colour and sound of their bus.
- A separation of the waiting and boarding zones, to promote faster boarding, is made possible by the light and soundscape.

Results: The bus station started service on 5 September 2019 and, with its beautiful design and innovative light and soundscape, it has added value to both passengers, the public transport system and the smart city. Early monitoring of the number of passengers using the bus station showed an increase in users. Due to Covid-19 and the restrictions that followed, the monitoring of the number of passengers was not continued. Once the situation allows, monitoring of the number of passengers will restart.

By 2022, the municipality of Umeå aims to ensure that 65 % of all travels are made using sustainable transport modes to reduce the city's carbon dioxide emissions. The bus station contributes to that goal by giving public transport a modern and futuristic touch, and by giving passengers waiting for the bus a space to relax. More efficient boarding, made possible by the audio-visual system, is good not only for the electric buses, but also for the public transport system economy.

Feedback from passengers on the first day of service included: "Futuristic and aesthetic," "exciting design," "beautiful lights," "surrounded by wonderful sounds," "cosy leaning pods," "fun," "multiple senses," "super with real-time notifications," "it feels warmer in the pods than outside them," "I don't mind waiting for the next bus," "awesome."

Connection to existing urban system: The bus station is in service as part of the municipality of Umeå's public transport system and is connected to their real-time system as well as their fibre net and electrical net.

Upscaling plans: The target of the public transport authority and public transport in Umeå was to become 100% fossil free by 2020, a goal that has now been achieved, but not only through the use of electric buses. Today, 25 electric buses operate the highest-load bus routes and 8 buses powered by HVO operates the supplementary bus routes (the first eight electric buses from the start-up project have been removed from service due to low operational reliability). Umeå has invested 21 M Euro in total including three charging stations, a charging infrastructure at the bus depot, electric buses and in other supporting actions like the BRT-station, Station of Being.

Replication assessment: There are great opportunities for replication either as a full concept or in-part, e.g. the design of the innovative pods and the meditative light and soundscapes which are connected to a realtime GPS-system.

Solution U6: E-charging hub & charging infrastructure

General description: Akademiska Hus will test a charging hub for e-vehicles (see Figure 10) that serves e-bikes, e-cars and promotes car-sharing. As e-vehicle charging can increase strain to the power system, different batteries and storage solutions - within this solution as well as a smart power control management-system, including a dynamic payment system for charging - will be tested. The integration of small-scale photovoltaic (PV) installation within the overall system and the upscaling of battery storage will also be explored. The overall aim for the e-charging hub is for it to become an "Energy-hub." VCC will also install a charging hub for e-vehicles in front of the hospital in Umeå.

Expected impact: The main goal of this solution was to even out power consumption and find an optimal distribution between building loads, battery storage and solar panels. The experience taken from this solution was expected to lead to further assessments of which size of battery plant would be optimal for different types of properties.

Current implementation stage: The installation of the system began in the summer of 2019 and is complete. After finalising the installation, the system is operational.

Innovation: The type of battery storage, the link between producing and consuming and the evaluation of input to allow this solution to be scaled up are innovations.

Connection to existing urban system: This solution is connected to the existing urban system because it delivers the additional electricity from its PV-plants to the buildings.

Connection to other smart solutions: This solution is connected to the U2 'Peak load management' solution because it helps decrease peak energy loads. This solution could also be a part of the U7 'Flexible green parking pay off' by being a very cost-effective sustainable mobility measure for private property owners. It will also be able to supply data that may be useful for U7.

Connection to existing urban system and citizens/users: The application is not intended to be directly connected to other urban systems, at least not at this stage. However, it will have an indirect impact on the usage of a range of different systems by encouraging more sustainable living.

Results: There were some initial difficulties in obtaining measurement data. The detection equipment needed to be replaced, including energy storage batteries. Now the batteries have been replaced and all parts deliver relevant data.

Upscaling plans: There are currently no upscaling plans. However, we are still working to update the model so that it is able to perform the correct dimensions based on the data we receive from this solution.

Replication Assessment: After further developing this model, we will be able to replicate this solution in the future.

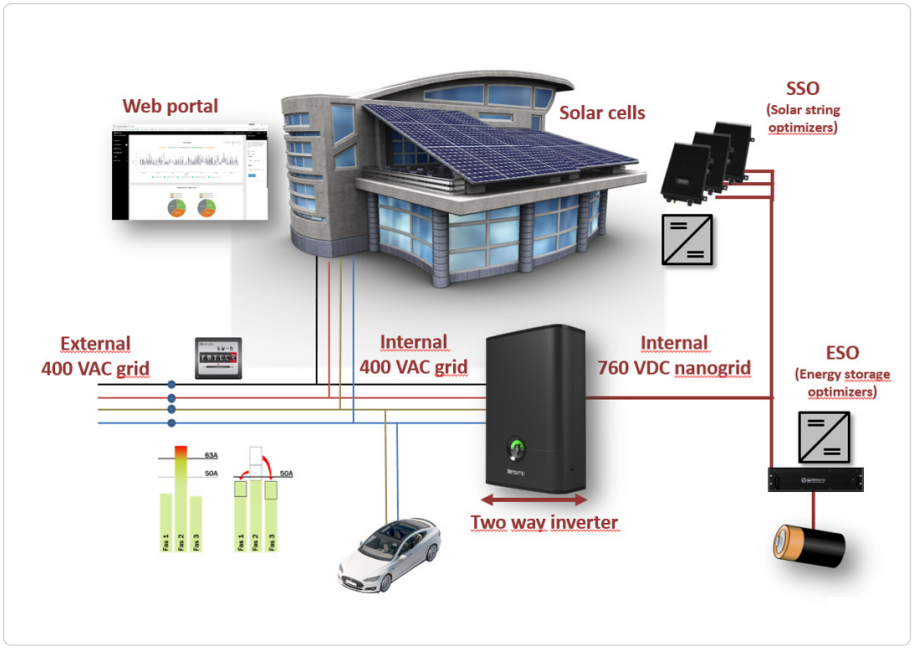


Figure 10: Charging hub. Source: Ferroamp

Solution U7: Green parking pay-off for flexible parking

General description: To help manage air quality in the centre of Umeå, the local authority has decided that no new workplace parking spaces shall be built in the central urban area. Property developers are therefore offered the possibility to access alternative pay-off schemes for parking places through Umeå Parking (UPAB), the municipal parking company, when they get planning permission.

In order to enable more sustainable travel to and from work, property developers have been offered a reduced fee for the cost of the parking pay-off through the "Green Parking Pay-off" scheme. In this case, the developer signs an agreement with UPAB in which they agree to implement measures to support sustainable travel for the users of the building.

Centrally located workplaces are attractive, and the densification of urban space leads to more travel within a city. One solution to ensure air quality does not decrease, but rather improves in the city centre, is to keep the number of car journeys down in this area. Consequently, Umeå has made a political decision that no more workplace parking places shall be built in the city centre. It is not a viable option to sustainably develop the city centre and, at the same time, provide car parking for all employees. Instead, the parking spaces should be reserved for visitors and residents. To achieve this, the municipality of Umeå and UPAB implemented a parking pay-off scheme. The parking pay-off scheme means that property owners can buy parking spaces instead of building them on their own property. The property owner then gets the parking solution at a lower cost since they are technically collective facilities.

Expected impact: This new model allows the property owner to take responsibility for employee travel to and from the property in other ways, rather than merely by offering car parking according to existing standards. The property owners receive a reduced parking standard fee if they pay a fee to a mobility management fund, connect the property to car sharing and arrange heated bicycle parking areas with changing rooms for employees that commute by bike. Property owners thus get a reduced parking standard, more attractive facilities and they participate in the creation of a better urban environment which strengthens their brand. UPAB is responsible for reducing the car parking standard fee for properties, in addition to the mobility management of resources on behalf of property owners, producing green travel and communication plans for properties and arranging parking solutions for employees outside the city centre.

Current implementation stage: The parking pay-off scheme was completed in May 2018. The municipality board agreed on the terms and criteria that property owners had to fulfil in order to get the reduction on standard parking spaces. The parking scheme is now part of an overall "offer" and comprehensive plan. This means that all property owners in Umeå that fulfil the criteria may choose to benefit from the possibilities of the Green Parking Pay-off.

Innovation: In June 2012, the pilot project "Effects of green parking pay-off - a future model for the dense and climate-smart city," was funded by the Swedish Energy Agency. The project partners were the Municipality of Umeå, UPAB and Balticgruppen AB. The project developed an evaluation method for the Green Parking Pay-off scheme. Full energy efficiency and savings potential were calculated for the pilot project.

Today, it is possible to use the Green Parking Pay-off for businesses and housing within the city centre. The Green Parking Pay-off primarily applies to new and additional buildings, but a re-assessment to include older buildings may be relevant. The Green Parking Pay-off provides incentives for the property owner to contribute to sustainable mobility patterns.

Connection to existing urban system and citizens/users: In order to reduce parking space needs, property owners must ensure that the property still fulfils its employees' mobility needs. This means having a car-sharing service, more parking spaces for cyclists and working with the City's mobility management team to increase the use of public transport to and from the property.

Upscaling plans: The Green Parking Pay-off scheme has already become a permanent model in Umeå.

Replication Assessment: This scheme has a high potential for replication in other cities.

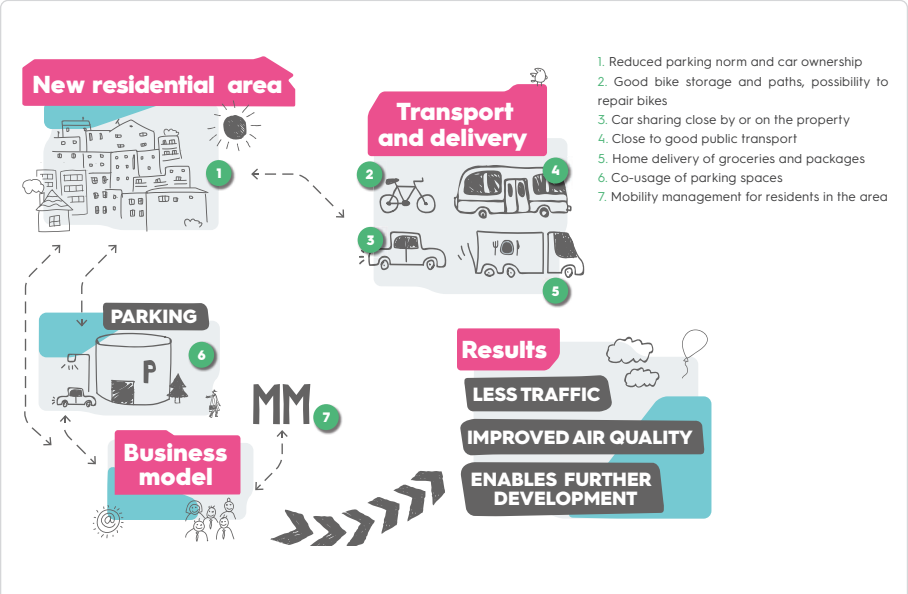


Figure 11: Flexible parking concept in Umeå.

Solution U8: Smart City open-data decision platform

General description: The smart city open-data decision platform aims to provide real-time visualisation as well as static data to show the impact of smart city interventions. It will also provide a way to quickly access and combine different data sets to examine results and, as such, to enhance the possibility of making timely, well-founded decisions for the council as well as for citizens. Bringing together different data sets as part of one platform enables a more uniform approach towards decision-making and the potential for a real improvement of quality of life.

By encouraging students at the university to use the platform - where it was introduced to different classes as a potential source of local data – we hope that students become familiar with the platform and that they will continue to engage with it when stating facts in community discussions. Non-data "experts" can also browse the data and look at it by using intuitively designed maps and charts.

Current implementation stage: Since Umeå realised that neither the resources nor the time were available to build an open-data decision platform from scratch, it was decided that one would be purchased to use as a foundation. The first step was to examine what could be found on the market. Initial research found that none of the products delivered the 'whole package,' so a procurement process was opened with a list of requirements. The procurement ended with a designated winner and our portal became public in the autumn of 2019: Opendata.umea.se.

Innovation: On the open-data platform, visitors will have the possibility to combine different data sets. Administrators can create dashboards to present/view specific data set combinations.

With this open-data platform, citizens are invited to use the collected data and share feedback on it. They can also combine data sets or analyse them to find the data they need to prove a point: "As I've always stated – there are more bike accidents in the area where the city decided not to make bike lanes."

However, there will also be cases where data sets have been combined that, in reality, have nothing to do with one another. To prevent this, it is crucial that the data owner, who publishes the data on the portal, also provides clear and distinct descriptions connected with the data, e.g. if there is a unit "L," what does it stand for? Is it large/ little/litre/etc., there must be no room for different interpretations!

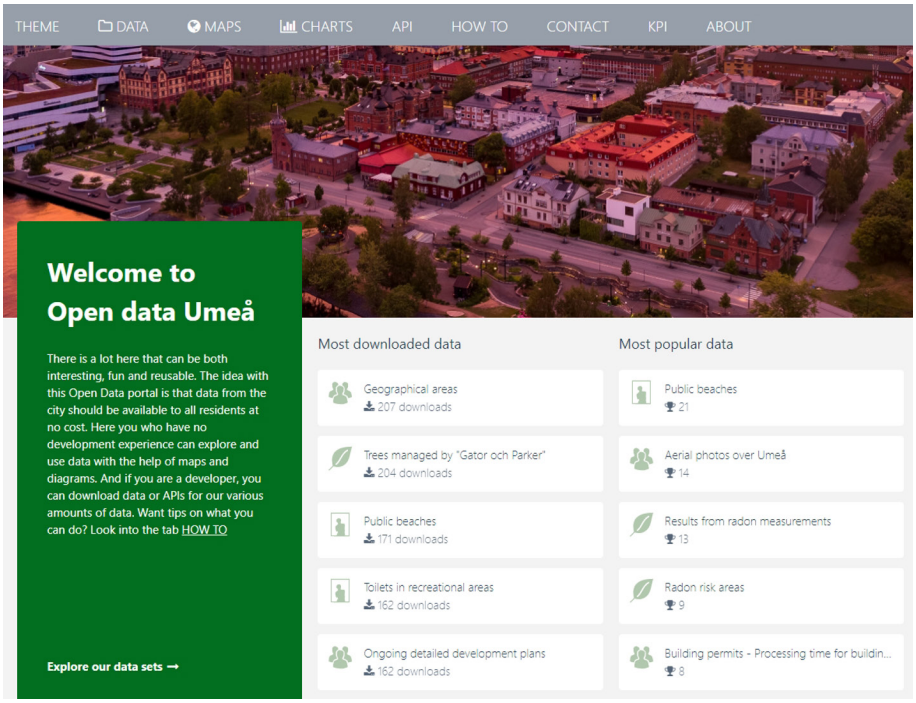
Umeå has had an open-data portal before. However, not one in which the users could both download data and view it directly in the portal. The portal will offer both text with good descriptions of the data, tables of the data, a map (if there is a position in the data set) and a chart (if data can be used in that way). In short – the portal offers something to everyone, not only to developers looking for an API.

Another new development is the possibility to combine different data sets. This feature will truly make it a smart city open-data decision platform.

Connection to existing urban system: By collecting different data and providing the possibility for analysis of multiple data sets, the possibility for strategic City planning is enhanced. With this portal, the aim is also to show data collected from different sensors throughout the city. However, providing real-time data to the platform may prove a technical challenge.

Adding real-time data for different services, opens up the possibility to monitor the impacts of different targeted interventions across the city.

Connection to existing urban system and citizens/users: Stakeholders that published data on the old open-data portal will be contacted, if they have not been already. If their data is valid for



Screenshot form Open data Umeå.

publication, the aim is to publish that data on the new portal along with other data. Data collected by the Municipality should also "automatically" be evaluated for sharing on the portal. This will be a slow process; the current way of working must be adapted. Once in place, the process for handling data should be relatively smooth and will be automatically updated and managed. To ensure citizen engagement in providing data to the portal, the idea has been presented at Umeå University, specifically to the department of computer science. The department is planning to use the platform as a data source for their students, both to find statistical data, but also to use the APIs provided by the platform.

Results: Today, we see a steady flow of traffic on our decision support platform. Sometimes there is a very visible peak in traffic, indicating that one, or several, data sets are being used by someone. Since the data sets are open, i.e. you can use them free of charge and without specifying for what purpose, we cannot know what they are used for. We are interested in knowing this information via the portal, however, so far no one has provided this. Sometimes we can see where it is being used, for instance there has been a lot of traffic on a data set showing the position for public beaches, both during this summer and in 2020. This was because a local newspaper published an article online about the public beaches in Umeå. In the article, there was a map showing the location for the beaches and that map came from our decision support platform.

Umeå energi, a partner in RUGGEDISED, has published data sets showing the results from their peak load shaving. By adapting the district heating use (meter effect) during critical occasions during a day when there is a high load, you can reduce the climate impact. The idea is that by reducing the use of district heating when there is the most pressure on the system, you can reduce the climate impact by avoiding using less climate-friendly fuels. One of the data sets can be found here.

They also publish data showing energy consumption in the different geographical areas in the municipality. Those data sets can then be used to focus different energy saving campaigns to different areas. Also, in the future, if different campaigns have been issued in different areas one might see if one of the campaign was more successful.

Different departments within the municipality have also discovered the benefits of sharing data via the platform. Alongside data transparency, they also use published data themselves to create informative dashboards that serve both citizens and departments for reporting. For example, Bygglov has created a dashboard that shows the expected waiting time – depending on the time of year - for citizens when they hand in a building permit application. Another example is Måltidsservice: the department responsible for the purchase/cooking/serving of food in preschools, schools and care and nursing homes within the municipality. They created a dashboard visualising statistics regarding food waste, number of portions, organic purchases and costs for meals.

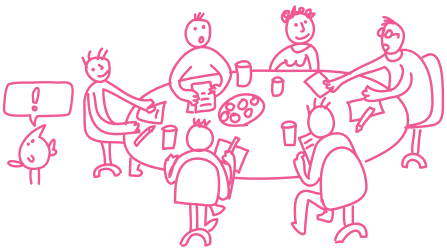
Lessons learnt: A mistake in the procurement process that we learned from is that some of the requirements we considered self-evident, e.g. an open data platform should not require registration in order to view the data, were not obvious to vendors. In hindsight, clearer requirements would have saved time spent on discussions with vendors who did not understand why they were rejected. In some cases, sharing how requirements were verified would have been beneficial.

The real challenge is to collect sufficient data on the platform and to convince stakeholders of the value of publishing and sharing data openly. This is much easier with a portal which has a visually attractive user interface, where contributors can see the data and understand that the combination of different data sets could be interesting. In some cases, they might even understand that citizens, when viewing data on the platform, could contribute missing data. Another factor to consider is the time savings associated with being able to direct citizens directly to the platform rather than needing to respond to individual requests.

Upscaling plans: Going forward more departments are expected to publish increased amounts of data as they start to see the benefits of it. There is also an ongoing discussion with municipal companies, and the hope is that they will also start publishing data on the platform (some are already doing it). Umeå have several goals regarding the climate and waste. Our aim is to get access to the data indicating progress, or lack of it, with regards to those goals. Once the data is shared as open data, the next step would be to create dashboards that visualizes the current state regarding reaching our goals.

Our upscaling plans also includes more sensor data to be published. To ensure that our portal will be used to its full capacity a recommendation has been made to the politics to formally make the decision that our "motto" will be open by default. The indications are that the decision will be taken in the spring of 2022.

Replication Assessment: Since Umeå's decision support platform is built as part of a purchased product, every city should be able to replicate the solution. As mentioned before, the real challenge is to convince stakeholders to publish data. The vendor for Umeå's decision support platform is the company Opendatasoft. Their price differs depending on functionality and size of municipality, Umeå's decision support platform comes at a cost of 195 000 SEK/year. The contract is for a service i.e. Opendatasoft maintenance the platform.



You can try Umeå's Open data platform on: **http://opendata.umea.se**

Solution U9: Demand Side Management

General description: For this solution, the demand side management system logs sensor data from different sources (i.e, LoRa sensors detailing occupancy, indoor climate, electricity use and radiator heat data and HVAC devices detailing occupancy and indoor climate data, weather station data with outdoor temperature data and time schedule data from the University facility booking system) and aggregates it into a single platform. This platform enables a new kind of analysis that shows the use and energy status of a building. Research results have diminished the need for facility areas while increasing the efficiency of facility usage. The results have also improved the management tool: for example by showing optimal indoor temperatures, unnecessary energy use and the actual energy usage of bookable rooms. Research has further contributed to improving the measurement method by analysing the accuracy of the sensor when logging information. While the solution will affect the buildings in terms of better management of energy use, better indoor climate and more efficient facility usage, the people using the buildings are unlikely to notice a difference in comfort or use. For planners, operating and service personnel, as well as energy operating technicians, the project will make a difference.

Expected impact: The overall goal of this solution was to find a model/tool for demand side management and to reduce the energy usage and climate impact of buildings as well as to increase facility usage in existing buildings. The tool helps to optimise facility services such as cleaning and waste management, and to improve the use of bookable rooms. The ambition is to reduce energy use by 5 to 30 % and also to decrease rental areas. The property owner, Akademiska Hus, owns and manages about 3.2 million square metres of property in Sweden and, including the tenants' use of energy, the proper management of this energy could be vital for reaching ambitious climate goals. In the future, the solution could potentially be used in any building.

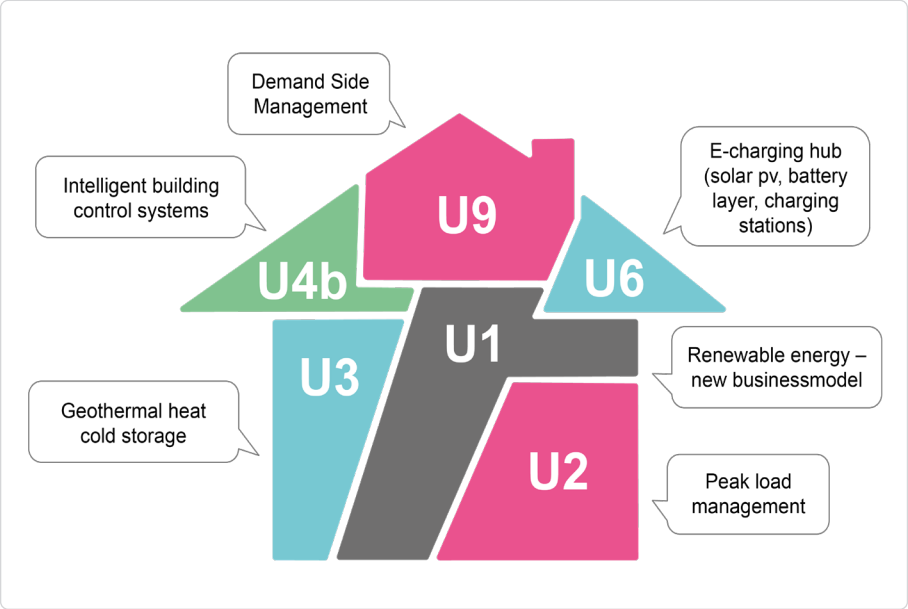


Figure 12: Umeå's connected smart city solutions.

Current implementation stage: About 1200 sensors have been installed in University buildings. 500 were installed during the demand side management project and the rest were installed during the upscaling phase. The sensors are aggregated into a single platform together with sensors placed in smart heat and ventilation devices, and also time-scheduling data and weather station data, to show the status of the building. This information is expressed in relevant key indicators such as facility use, i.e. when a room is booked or not, occupancy in the daytime, unnecessary electricity use and unnecessary heat supply. Because of the results, changes in facility use have been made, such as intensifying the booking hours and reducing the overall rental area.

Innovation: A wide range of different sources generates comprehensive building data. Such data has traditionally been analysed separately. By aggregating and analysing building data holistically, in a tool capable of incorporating different data sources, it is expected that new ways to improve a building's energy efficiency and usage, in addition to reducing climate impact will be identified.

Connection to other smart solutions: For this project, the Building Office and the Department of Applied Technology and Electronics at Umeå University work together with the property owner, Akademiska Hus. The solution could complement U2 'Peak load management' and U4B 'Intelligent building control,' where the local energy company Umeå Energy is a main partner. The installed sensors will also be a part of a larger project for which a digital 3D-twin is going to be developed for the Umeå Campus.

Results: The project, and related research, have resulted in some scientific papers, Master's dissertations and a PhD thesis. For example, the analysis and the demand side approach have helped us to identify the energy saving potentials of different types of energy systems. See Figure 13 below.

The results have also shown that the location of a sensor could affect the results and that the combining of sensors that are placed below the desk and in the ceiling provides the most accurate information if occupancy is to be measured.

A third result is the continuously analysis of the facility usage. Analyses have shown that booked rooms remain empty for about a third of the booked time, that classrooms are completely empty for at least half the day, and that the average use of an office is about 30 percent of a working day under normal circumstances. Furthermore, it has been observed that the heating system is switched on even though it is not needed. Despite growing numbers of students and a new integration of a police academy, we have been able to cut down our used area by 6 percent corresponding to about 11,500 m^2 between 2013 and 2020. Thanks to better visualisation and communication of actual occupancy, we have been able to transform 40 lecture halls to accommodate other needs. The calculated CO_2 impact of avoiding to build new thanks to this manoeuvre is estimated to 1,320,000 kg CO_2. See Figure 16 for facility usage of lecture halls.

Out of the experiences of the Demand Side project and the results of performed analysis have led to a new approach then planning the future facility use. Step 1 is always try to diminish the facility area, the next step (2) is to increase the existing facility usage. Step 3 is to rebuild existing areas and the final step (4) is to build new (smart and climate friendly facilities).

Upscaling plans: In the demand side management project 500 LoRa sensors were installed and out of those and existing HVAC devices sensors in the Natural Sciences Building as well as data of weather station and a time schedule system, the analysis tool on Demand Side management were developed. Out of the results of the tool, another 700 LoRa sensors have been installed and all HVAC at the Umeå Campus were included in the tool, so it covers all facilities at Umeå Campus.

Replication Assessment: The model and the combining of sensors and time scheduling data could be used of any organisation, facility tenant or property owner. Since the model identify and show empty spaces and efficiency potentials the replication potential is great. The goal is for the solution to potentially be used in any building in the future. At present, one other University in Sweden (Örebro) has been equipped with similar sensors and there are planned that other will follow, however the property owner owns and manages about 3.2 million square metres of property in Sweden, and that, including the tenants' use of energy, could be vital for reaching ambitious climate goals. If all organisations can save five percent of the space used or reduce the need to build new facilities, the environmental impact at a national or European Would be very enormous. In Sweden other Universities will follow.

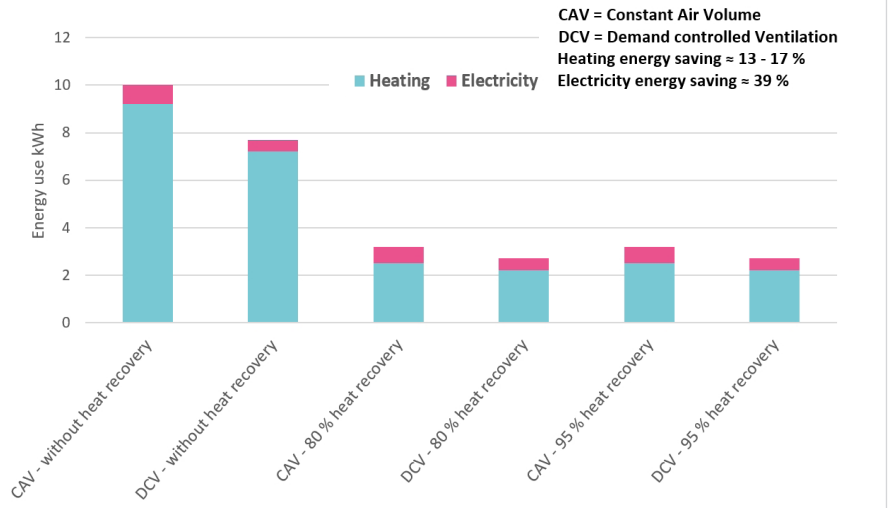


Figure 13: Energy saving potential for different types of energy systems; conventional heat recovery, 80 % heat recovery and 95 % heat recovery.

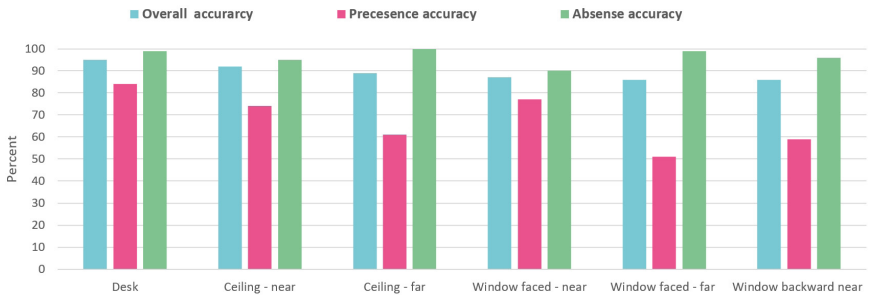


Figure 14: Schematic layout of one of the offices, detailing accuracy of occupancy detection with different PIR sensor positioning.

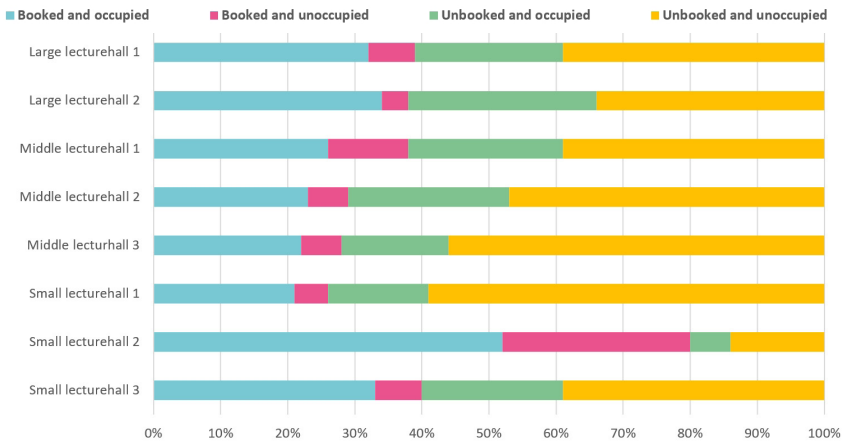


Figure 15: Use of facilities.

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Authors
Umeå Municipality, Umeå Energi, Umeå University, Upab, Region Västerbotten, Akademiska Hus

Design
unger+ kreative strategen GmbH

Layout
Stephan Köhler (ICLEI)

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

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

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RUGGEDISED
Designing smart, resilient cities for all

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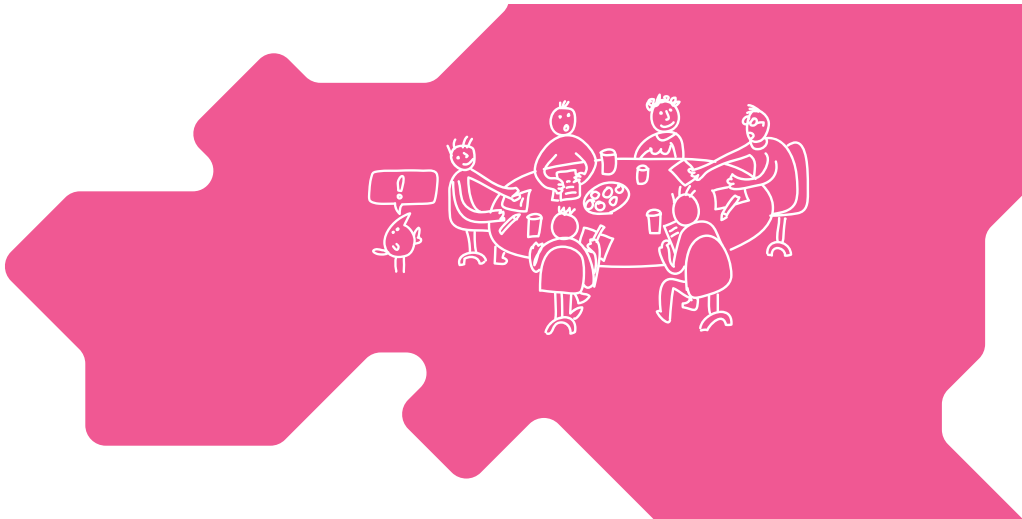

Designing smart, resilient cities for all

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BRNO . PARMA . GDANSK

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

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