IRIS

Integrated and Replicable Solutions for Co-Creation in Sustainable Cities

Project Acronym:	IRIS
Project Full Name:	Integrated and Replicable Solutions for Co-Creation in Sustainable Cities
Grant Agreement:	No 774199
Project Duration:	5 years (starting 1 October 2017)

Deliverable D7.8

Preliminary report on Gothenburg lighthouse demonstration activities

Work Package:	7
Task:	
Lead Beneficiary:	19-GOT (City of Gothenburg)
Due Date:	31 September 2021 (M48)
Submission Date:	29 November 2021 (M50)
Deliverable Status:	Final
Deliverable Style:	R
Dissemination Level:	PU
File Name:	D7.8_Preliminary_report_on_Gothenburg_lighthouse_demonstration_activities.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 774199

Authors

Surname	First Name	Beneficiary
Bjärkvik	Hanna	METRY
Löveryd	Per	AH
Lund	Emma	TRIV
Nordström	Camilla	GOT
Ollila	Susanne	CHALMERS
Pavic	Eva	JSP
Reuter Metelius	Anna	GOT
Selberg	Peter	Riksbyggen
Torkelsson	Joel	METRY
Westling	Björn	JSP

In case you want any additional information, or you want to consult with the authors of this document, please send your inquiries to: irissmartcities@gmail.com.

Reviewers

Surname	First Name	Beneficiary
Lantto	Kim	GOT
Massink	Roel	UTR

Version History

Version	Date	Modifications made by
1.0	29-11-2021	Final version to be released to the EC

Disclaimer

This document reflects only the author's view. Responsibility for the information and views expressed therein lies entirely with the authors. The Innovation and Networks Executive Agency (INEA) and the European Commission are not responsible for any use that may be made of the information it contains.

Executive Summary

The IRIS project is now well into its fourth year of operation. In the Lighthouse City of Gothenburg, the project has resulted in a large number of new solutions in the areas of renewable energy sources, energy storage and management, e-mobility, open data platforms and citizen engagement. Most of these solutions have been implemented and are now in the operation and evaluation stage.

This deliverable gives an overview of the current state of the Gothenburg demonstrators and what preliminary results and data have already been gathered. It aims to present the content in an accessible and non-technical manner to serve as useful information and inspiration to other cities, organisations and individuals looking for solutions that improve sustainability, resource efficiency, democracy and quality of life in cities.

Transition Track #1, In this transition track, the objective has been to demonstrate a Positive Energy District (PED), a district that annually produces more electricity and heat than it consumes. To achieve this, a combination of energy-saving measures, energy storages, renewable energy sources and energy management systems have been designed in the housing cooperative Viva, most of which are implemented and in use by M48.

Preliminary results are promising although there is still some way to go towards reaching a positive energy balance for the district.

In Transition Track #2, the key message is: In future energy systems, peak power demands will stand for a large part of operational costs and negative environmental impact. In this transition Track the focus is to how to store energy both electric and thermal cooling energy to reduce the power demand in the energy systems.

Main preliminary results are: PV/battery/DC network is operating and successfully cuts peaks in electricity consumption. PCM thermal storage for cooling is showing less capacity than anticipated, this discrepancy is now being investigated.

In Transition Track #3, the key message is: The mobility service has shown to be attractive and appreciated among users, it is scalable and replicable and has attracted great interest from real estate owners. However, MaaS systems offer complex challenges, both from technical integration and management of stakeholder interests in the value chain.

Main preliminary results show that in the Viva complex, MaaS usage is high, both for e-bikes and e-cars and satisfaction ratings from users are high. Private car ownership among Viva residents is significantly lower than the city average. In the campus area demonstration, results are yet difficult to interpret due to the impact of the Covid-19 pandemic.

In Gothenburg the IRIS project has demonstrated two different solutions in TT#4:

The CIM (City Information Model) pilot project which is an implementation of tools for collecting and sharing of data from building projects with support by FIWARE components. The main collected data is BIM data – Building Information data.

The Energycloud have been implemented and is a local version of a cloud for collecting data within the energy system. The local system has been delimited to three universities and their landlords in the Gothenburg region.

In Transition Track #5, the City of Gothenburg has worked with different types of civil society dialogues in various operations and processes, including Minecraft, a digital tool for engaging younger citizens regarding for instance the development of a detailed plan for an area. The Inclusive Life Challenge is a concept developed for creating an arena were the city and its citizens can collaborate. Within urban development, a public tool/platform has been developed in 2012; Min Stad ("My City") and will be further developed to strengthen citizen engagement. ME-model, is a framework created to integrate the experience and learning from the three demonstrators: Minecraft, Inclusive City Life Challenge and Min Stad.

The ERO application was developed and demonstrated in the HSB Living Lab, for nudging tenants to be aware of their energy use, and finally there is the VR/AR BIM application within the building "A Working Lab" where users can view BIM data and sensor data through a smartphone or a VR headset.

The next and final steps of the IRIS Gothenburg project include continued implementation and data collection of demonstrators, close collaboration with Gothenburg City groupings to achieve higher impact, dissemination, and upscaling within the City, as well as advocacy work to strengthen the political will to continue the innovation process

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

Abbreviation	Definition
EU	European Union
WP	Work Package
MaaS	Mobility as a Service
PV	Photovoltaic
AC	Alternating Current
DC	Direct Current
PCM	Phase Change Material
CIM	City Information Model
BIM	Building Information Model
CIP	City Information Platform
CKAN	Comprehensive Knowledge Archive Network
AR	Augmented Reality
VR	Virtual Reality
V2G	Vehicle to Grid
BIPV	Building Integrated Photovoltaics
Brf	Bostadsrättsförening (Housing cooperative)
EMS	Energy Management System
AWL	A Working Lab
HVAC	Heat, Ventilation, and Air Conditioning
TES	Thermal Energy Storage
SAP	Sodium Polyacrylate
ME	Citizen Engagement (Sw. “Medborgarengagemang”)

1 Introduction

1.1 Scope and objectives

This Deliverable constitutes a preliminary report on the intermediate results of the Gothenburg lighthouse demonstration activities, comparing these results with the ambitions, specifications, and planning of the Gothenburg demonstration activities. It aims to describe in a non-technical and accessible way how the Gothenburg Lighthouse demonstrations have progressed, and what preliminary results have emerged.

Furthermore, the Deliverable aims to serve as a "teaser" and a first step into the IRIS universe for readers looking to profit from the knowledge and experience gathered in the project, for replication, upscaling or inspiration in their own cities or organisations.

1.2 Lighthouse demonstration project

The IRIS Gothenburg Lighthouse demonstration project musters a well-rounded and multi-disciplinary team including large and small enterprises, City administration departments, real estate owners, utilities and higher education and research institutions. Together, this team addresses the challenges set out in the IRIS Description of Activities.

The demonstration activities in IRIS Gothenburg are mainly centred around the Chalmers University of Technology campus. Here, the brf Viva complex (Transition Track #1, the AWL (A Working Lab) building (Transition Tracks #2 and #5) and the HSB Living Lab (Transition Tracks #1 and #5). Outside of this area, activities dealing with the City Innovation Platform (Transition Track #4) and Citizen Engagement (Transition Track #5) take place at various locations in the city. Fig 1. shows an aerial view of the main demonstration area with the buildings highlighted.

Figure 1. IRIS Gothenburg Demonstrations

IRIS project strategy is built around 5 interdependent Transition Tracks enabling the transition towards reduced energy demand and increased shares of renewables and e-mobility in the urban energy and mobility systems. Realizing citizen engagement, cocreation of inclusive information services for citizens are regarded as a crucial drivers and enablers in the urban energy transition. Therefore, citizens play an important role in the lighthouse demonstration activities. As outlined above, the lighthouse cities face common as well as district specific challenges. The IRIS lighthouse cities will address these challenges by integrating and demonstrating solutions belonging to five both indispensable and promising IRIS Transition Tracks

IRIS Transition Track #1: Smart renewables and closed-loop energy positive districts: Integrating (a) a high share of locally produced and consumed renewable energy at district scale, (b) energy savings at building level reducing the citizens' energy bill and (c) energy savings at district level. Demonstrated solutions integrate high renewables penetration like district scale PV and biomass for district heating, near zero energy housing retrofit, energy efficient low temperature district heating and smart public lighting that is energy efficient, powered by renewables and connected to the district energy system

IRIS Transition Track #2: Smart Energy Management and Storage for Grid Flexibility: Integrating smart energy management and renewable energy storage for (a) maximum profits of renewable power/heat/gas, (b) maximum self-consumption reducing grid stress and curtailment, and (c) unlocking the financial value of grid flexibility. Demonstrated technical solutions include smart ICT to interconnect energy management systems at home, building and district level, and to integrate maximal renewables production (track 2), V2G storage in e-cars operated in car sharing systems (track 3) with additional stationary energy storage.

IRIS Transition Track #3: Smart e-Mobility Sector: Integrating electric vehicles and e-car sharing systems in the urban mobility system offering (a) local zero-emission mobility, (b) lower household mobility costs, and (c) smart energy storage in V2G car batteries. Demonstrated solutions include extensive deployment of (V2G) e-cars, exploitation of (V2G) e-cars in local car sharing systems, and district-wide smart (V2G) charging stations powered mainly by renewables.

IRIS Transition Track #4: City Innovation Platform (CIP): Cutting edge information technology and data framework enabling (a) the above-mentioned solutions, maximising cost-effectiveness of the integrated infrastructure. Next, the City Innovation Platform with open, standards-based application program interfaces (APIs) provides meaningful data and information services for households, municipality and other stakeholders, allowing for a Data Market with new business models. A common architecture, harmonized data models and a sustainable data governance plan ensure the interoperability and replicability of the solutions, transferring them from city to city. The City Data Market and the service marketplace manage access to all data and services, with appropriate licenses and flexible pricing models in and across cities and allowing real time KPI monitoring and benchmarking of smart energy and mobility performances.

IRIS Transition Track #5: Citizen engagement and Co-Creation: Design and demonstration of feedback mechanisms and inclusive services for citizens to achieve that they are intrinsically motivated to (a) save energy, (b) shift their energy consumption to periods with redundant renewables, (c) use electric vehicles and (d) change the vehicle ownership culture towards a use or common mobility assets culture. Demonstrated solutions include game-theory based engagement methods and instruments ranging from co-creating infotainment apps, local school campaigns, offering training on the job to students living in the district by partaking in the demo activities, competitive energy games using the home energy management system, energy ambassadors creating local energy communities, to crowdfunding creating a sense of being part of the solution.

The five transition tracks focus on energy and mobility solutions that will be demonstrated by all lighthouses, but will include some specific city solutions as well, allowing the lighthouse cities to put their own accents responding to their local conditions and challenges. The demonstration results will be replicated in other districts in the lighthouse cities, as well as in the follower cities, which can mix and match the demonstrated solutions according to their needs, paving the way to worldwide replication.

Along with demonstration of integrated solutions, new business cases will be developed and tested in order to accelerate the worldwide market uptake of the demonstrated solutions. Beyond demonstration and implementation, extensive monitoring and evaluation of each implemented measure will be carried out in the three lighthouse cities. Energy and CO2 savings, as well as other environmental and socio-economic impacts, benefits and lessons learnt will be quantified, assessed, and reported in order to accelerate replication and knowledge dissemination

IRIS Objectives

Objective 1: Demonstrate solutions at district scale integrating smart homes and buildings, smart renewables and closed-loop energy positive districts.

Objective 2: Demonstrate smart energy management and storage solutions targeting Grid flexibility

Objective 3: Demonstrate integrated urban mobility solutions increasing the use of environmentally friendly, alternative fuels, creating new opportunities for collective mobility and lead to a decreased environmental impact

Objective 4: Demonstrate the integration of the latest generation ICT solutions with existing city platforms over open and standardized interfaces enabling the exchange of data for the development of new innovative services

Objective 5: Demonstrate active citizen engagement solutions providing an enabling environment for citizens to participate in co-creation, decision making, planning and problem solving within the Smart Cities.

Objective 6: Put in practice bankable business models over proposed integrated solutions, tested to reduce technical and financial risks for investors guaranteeing replicability at EU scale.

Objective 7: Strengthening the links and active cooperation between cities in a large number of Member States with a large coverage of cities with different size, geography, climatic zones and economical situations.

Objective 8: Measure and validate the demonstration results after a 3-years large-scale demonstration at district scale within 3 highly innovative EU cities.

1.3 Structure of the deliverable

This Deliverable is divided in five main parts, each giving description of the state and preliminary results (where available) of the demonstration activities in each of the above-mentioned Transition Tracks. Each Transition Track chapter also touches on possible exploitation schemes and business models associated with the demonstrators.

The concluding chapter deals with what wider impact the IRIS project and its activities have had, and what tangible results have been produced on the city level.

The Appendixes contain technical information for the benefit of the reader that is looking for more details on selected subjects.

2 Preliminary Results of Transition Track 1

KEY MESSAGE

In this transition track, the objective has been to demonstrate a Positive Energy District (PED), a district that annually produces more electricity and heat than it consumes. To achieve this, a combination of energy-saving measures, energy storages, renewable energy sources and energy management systems have been designed in the housing cooperative Viva, most of which are implemented and in use by M48. Preliminary results are promising although there is still some way to go towards reaching a positive energy balance for the district.

2.1 Overview

Collectively, the housing sector must do better. The energy used in buildings, and the climate impact that is a result of it must be reduced, rapidly and substantially. The demonstrated measures in this Transition Track are all put in place to achieve this, through the two buildings they are installed in. The demonstrators are, as stated in the project application:

1) Demonstration of at least 200 kWh electricity storage in 2nd life automotive (bus) batteries powered by 140kW local PV,
2) Demonstration of heating from geo energy with heat pumps (2-300 m deep boreholes),
3) Demonstration of cooling from geo energy without chillers,
4) Demonstration of local energy storages consisting of water buffer tanks, structural (thermal inertia of the building) storage and long-term storage in boreholes,
5) Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block,
6) Development and demonstration of advanced Energy Management System to integrate PV, DH, grid and all abovementioned storage options to achieve peak shaving and minimal environmental impact,
7) Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process

Figure 2. Aerial view of HSB Living Lab on Chalmers campus

In the full-scale housing lab HSB Living Lab (Figure 2), much was already achieved when IRIS begun, albeit only shortly before, and so the demonstration included is a retrofit of façade-integrated photovoltaic panels, demonstrator 7 (Figure 3). These panels were installed in multiple directions for evaluation purposes, including an economic comparison of using PVs as a façade material.

This demonstrator has shown that PVs on facades can be an excellent idea. An important factor here is that the PV panels are used as the primary rain screen for the building, which means that it replaces another façade material, and the investment is not simply an added cost but an alternative cost. And with the long service life of the panels and the continuous values it creates in the electricity it generates, life cycle costs are quite encouraging.

Figure 3. The HSB Living Lab after installation of Building Integrated PhotoVoltaics.

In the housing cooperative Riksbyggen Brf Viva (Figure 4), or Viva for short, the energy system is constituted of demonstrators of varying level of innovation, demonstrators 1-6). Some are entirely commonplace, with just a high level of standard, where others are so novel that they are still in development and have just recently begun operations.

Figure 4. Brf Viva as seen from Johanneberg Science Park

Three principles guided the design of the system and the selection of its components.

First, minimize the demand for energy and power. This was achieved through a well-insulated building with high thermal inertia, efficient appliances and automated lighting controls. This is commonly done in the context, and thus not included in the measures in IRIS.

Second, local renewable energy production. PV panels on the roofs for electricity and a borehole and heat pump system for heating and cooling, all of which are included as measures in IRIS. These are increasingly frequent in the Swedish housing stock, but it is primarily their part in the system that is of interest for the evaluations done in IRIS.

Third, store or sell the excess. In that order. The electricity storage is, to the best of our knowledge, first of its kind in the world. In collaboration with the Volvo bus manufacturing company, batteries which have been in use in the buses for around three years are given a second life being applied as a stationary electricity storage in Viva. There, the batteries have two tasks: to reduce the amount of electricity from the PVs that is sold to the grid, since this would be less profitable under current Swedish regulations; and to balance electricity use over time to reduce peak power use for the whole Viva. Viva also uses insulated water tanks for thermal storage and buffering and is helped by the high thermal inertia of the building structure.

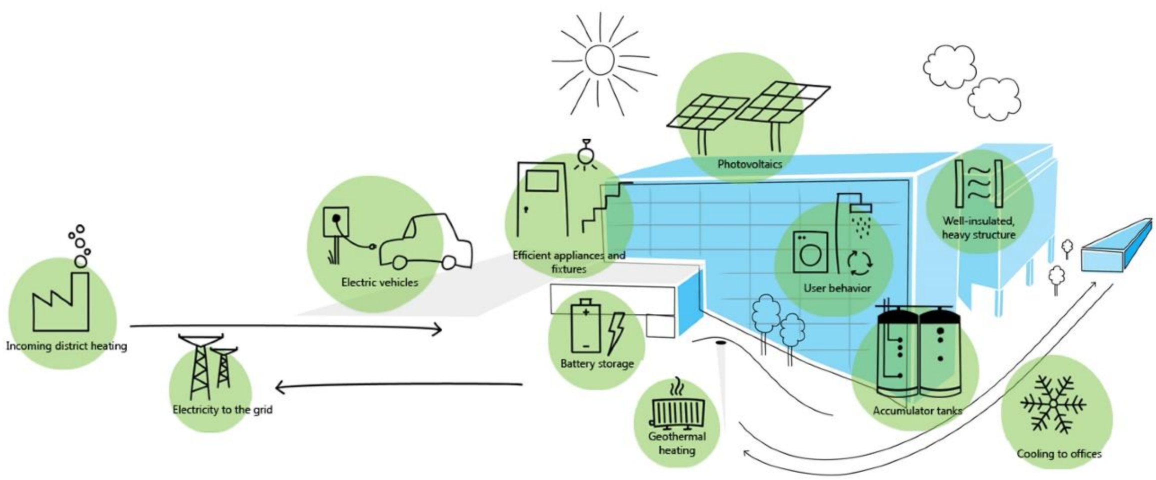


Figure 5. The components of the energy system in Riksbyggen's housing association Viva

At this point in time, when Viva has been fully operational and with full occupancy for almost three years, the main activities revolve around three principal things; development and problem solving to be able to launch the few remaining measures, which also includes finding agreements with partners outside IRIS; improvements and adjustments of the measures that are expected to work better; and continuous measuring and evaluation of the energy system and all its components.

2.2 Implementations

Most of the planned demonstrators have been fully implemented according to plan:

- *Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process.* This was done in HSB Living Lab and is now fully evaluated.
- *Demonstration of heating from geo energy with heat pumps (2-300 m deep boreholes).* Completed and works well. Unfortunately, the energy performance of the buildings themselves has turned out lower than expected, regarding heat distribution and degree of airtightness, causing the heat pumps to use more electricity than expected.
- *Demonstration of at least 200 kWh electricity storage in 2nd life automotive (bus) batteries powered by 140kW local PV.* This was fully implemented, but due to some problems with the control systems, the battery storage has worked with reduced capacity during parts of the period.

Some have been partially completed:

- *Demonstration of local energy storages consisting of water buffer tanks, structural (thermal inertia of the building) storage and long-term storage in boreholes.* The water tanks are fully operational, and the structural storage is a passive system that always has an effect. The long-term storage in boreholes, however, is dependent on the *seasonal energy trading*, see below.
- *Development and demonstration of advanced Energy Management System to integrate PV, DH, grid and all abovementioned storage options to achieve peak shaving and minimal environmental impact. This demonstrator* has been implemented with a reduced functionality. The communication between the various control software for these components was unsurpassable for some time, which is why the start of operations did not include all components. Like Gall's Law states: "All complex systems that work evolved from simpler systems that worked. If you want to build a complex system that works, build a simpler system first, and then improve it over time." This demonstrator is now in the improvement phase.

And some are still underway:

- *Demonstration of cooling from geo energy without chillers,* and *Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block.* Both of there are entirely dependent on the connection between Viva's energy system and that of a neighbouring office building, with an owner not part of IRIS. After a few years of trying, funds and forms for the collaboration are now agreed upon and the installations have been ordered. The system is expected to be operating around the time when this report is finally submitted.

2.3 Preliminary results

Much to the satisfaction of everyone who has been involved in the development of Brf Viva, surveys among the residents mainly contain positive feedback.

In the questionnaire on indoor thermal comfort which was carried out as part of the certification for the Swedish system "Miljöbyggnad", roughly "Environmental Building", most respondents in each of the six buildings say that the thermal comfort is better than acceptable. This varies between 50 % and 78 % in winter, and from 76 % and all respondents in summer. Unfortunately, some also say that the thermal comfort is worse than acceptable, mainly during the winter period. Thorough efforts have been taken to find and fix different problems or faults that cause this dissatisfaction.

A large study of the perceived housing qualities in Brf Viva, carried out by researchers from the architecture department of Chalmers University of technology (also a project partner in IRIS), return similarly positive results. When asked about whether Viva is a housing project that supports a sustainable lifestyle, a majority answers in the affirmative, averaging 3,52 on a scale from 1 to 5. From their written motivations, however, it is clear that most residents do not think of choosing to live in a building with an ambitious energy system as a lifestyle choice. Electrified or human-powered mobility, waste management, opportunities to repair furniture and sharing of some household appliances would be things more closely associated as lifestyle choices. One exception is individual metering of energy and water.

In the same study, when asked if the technical solutions in Viva make it a sustainable housing project, the agreement is much higher. More than half answer “5 - completely agree”, and the average is 4,29. When asked about it this specifically, they say that these solutions are “timely” or “very good”. One says that these solutions make buildings “less unsustainable”, and one states that “mentioned technologies definitely are a part of sustainable building. It is surely possible to do more, but this is a good start”. It is like it is expected of a housing developer of good reputation to work hard with improving these more or less hidden systems, to supply residents with comfort at a steadily reducing environmental cost.

Some of the experience from the stakeholders involved in Viva are:

- Collaboration partners (Gothenburg Energy and Volvo) joined the project a little late, and therefore could not contribute with their preconditions in the very first stage.
- Differing interests and perspectives from the actors that together form an energy system. This gives us different ways of optimizing the energy monitoring system, differing ideas of which rules and variables should be allowed to manage the energy system. “Good” meant different things for the different actors.
- Fire safety regulations are not up to date for systems with reuse of bus batteries. Dialogue with fire department was reactive, not proactive. Ideally, an actor of this importance should have been a cooperation partner.
- Pipes with cooling water that connect the two buildings (Viva and CTP) are situated in the ground owned by the municipality. This results, in this case, in a short term guaranteed lease period. Which is a bad thing since it brings an uncertainty to the service life of the demonstrator.

Since many measures have been recently or partly implemented, Viva is still lacking a consistent long-term measurement for all measures. There is however data for the whole system and for the individual implemented measures. The quality of the data is generally good, albeit some strange signals from individual meters. Some in data to KPI-calculations overlap, making it more difficult to assess the benefits of the measures one by one. Also, some information is owned by other project partners, outside of IRIS, and is expected to be delivered soon.

The preliminary data has been gathered from measurements, verified, and collected by RISE and handed over to CERTH for calculating results for individual KPIs.

Main KPI's include:

(i) sub-district energy consumption (target: <24 kWh/m^2/a),
(ii) peak power shaving (target: >80% reduction in peak power compared to control)
(iii) and net energy surplus on annual basis (target: >10 MWh/a)
(iv) Energy savings (67 kWh/m2/y, or totally 1,5 GWh/y energy saving compared to average Swedish buildings
(v) Integrated PV power (420 kW)

Table 1 Demonstration of at least 200 kWh electricity storage in 2nd life automotive (bus) batteries powered by 140kW local PV

Parameter(s)				**2019**	**2020**	**2021**
Electric energy production by RES [kWh/year]				51718	137873	50682
Electric energy consumption [kWh/year]				393937	696197	349016
The CO_2 coefficient of electricity used in base case [t CO2/MWh] (national emission factor for Sweden)				0,023		
KPI	2019	2020	2021	GA- Target		
Carbon dioxide Emission Reduction [t/year]	1,19	3,17	1,17	15-20%, or 10 metric tonnes.		
Degree of energy self-supply by RES	13,1%	19,8%	14,5%	Brf Viva's degree of self-supply for **electrical** energy is expected to vary between 10% and 60%.		

Table 2 Demonstration of heating from geo energy with heat pumps (2-300 m deep boreholes)

Parameter(s)				**2019**	**2020**	**2021**
Thermal energy production by RES [kWh/year]				364975	712206	424972
Thermal energy consumption [kWh/year]				390538	783832	475526
The CO2 coefficient of baseline heat production [t CO2/MWh] (emission factor for the district heating grid in Gothenburg)				0,074		
Electricity consumption of the heat pump [kWh/year]				120873	217709	127641
The CO2 coefficient of baseline electricity production [t CO2/MWh] (National emission factor for Sweden)				0,023		
KPI	2019	2020	2021	GA- Target		
Carbon dioxide Emission Reduction [t/year]	24,2	47,7	28,5	90% reduction.		

Degree of energy self-supply by RES	93%	91%	89%	Varying between 0% and 100% for **thermal** energy.[1]

Table 3 Demonstration of cooling from geo energy without chillers

KPI	Unit	Definition	Prel results	Source	Target
Degree of energetic self-supply by RES	%	Ratio of locally produced energy from RES and the energy consumption over a period (e.g. month, year)	Not yet available	SCIS	(iii)
Carbon dioxide Emission Reduction	tonnes CO2/year	Reduction of emissions of carbon dioxide related to measure.	Not yet available	SCIS	
CO2 reduction cost efficiency	Euro/ton CO2 saved per year	Costs in euros per ton of CO_2 saved per year	Not yet available	CITYkeys	

Table 4 Demonstration of local energy storages consisting of water buffer tanks, structural (thermal inertia of the building) storage and long-term storage in boreholes

Parameter(s)	2020	2021		
Storage capacity installed [kWh]	970			
KPI	**2019**	**2020**	**2021**	**GA- Target**
Storage capacity installed [kWh]		970		970 kWh in tanks. N/A for boreholes and structure.

Table 5 Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block

KPI	Unit	Definition	Prel. results	Source	Target
Peak load reduction	%	Reduction in maximum peak load of a building or a group of buildings.	Not yet available	SCIS	(ii)

[1] More self-supply is not always better. Remember that DH in Sweden is largely comprised of waste heat, and thus has a very low carbon intensity. It is in many cases more beneficial from an emissions point of view to use DH.

Reduced energy cost for consumers	Euro/m2	Reduction in cost for energy consumption on an aggregated level, based on energy savings and current energy prices.	Not yet available	IRIS	
			Not yet available		
Carbon dioxide Emission Reduction	tonnes CO2/year	Reduction of emissions of carbon dioxide related to measure.	Not yet available	SCIS	
CO2 reduction cost efficiency	Euro/ton CO2 saved per year	Costs in euros per ton of CO_2 saved per year	Not yet available	CITYkeys	

Table 6 Development and demonstration of advanced Energy Management System to integrate PV, DH, grid and all abovementioned storage options to achieve peak shaving and minimal environmental impact

KPI	Unit	Definition	Prel. results	Source	Target
Energy savings	MWh/year	The reduction of the energy consumption to reach the same services (e.g. comfort levels) after the interventions, taking into consideration the energy consumption from the reference period.	TBA	SCIS	(i)
Peak load reduction	%	Reduction in maximum peak load of a building or a group of buildings.	TBA	SCIS	(ii)
Increased system flexibility for energy players	%	The change in load capacity participating in demand side management before and after the measure.	TBA	SCIS	

Degree of energetic self-supply by RES	%	Ratio of locally produced energy from RES and the energy consumption over a period (e.g. month, year)	TBA	SCIS	(iii)
			TBA		
Carbon dioxide Emission Reduction	tonnes CO2/year	Reduction of emissions of carbon dioxide related to measure.	TBA	SCIS	
CO2 reduction cost efficiency	Euro/ton CO2 saved per year	Costs in euros per ton of CO_2 saved per year	TBA	CITYkeys	

Table 7 Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in roof and façade renovation process

Parameter(s)	2019	2020	2021
Electric energy production by RES [kWh/month or year]	12303	11564	5446
Electric energy consumption [kWh/month (year]	84147	105616	52118
The CO2 coefficient of baseline electricity production [t CO2/MWh] (National emission factor for Sweden)	0,023		
The CO2 coefficient of PV electricity production [t CO2/MWh]	0		
Annualized investment cost for energy/CO2 related measures [€/y]	2100	2100	2100
Running costs related to energy/CO2 measures [€/year]	200	200	200

KPI	2019	2020	2021	GA- Target
Degree of energy self-supply by RES	15%	11%	10%	19 % of electricity used in the building
Carbon dioxide emission reduction [t/year]	0,28	0,27	0,13	0,525 tonnes CO_2 reduction
CO2 reduction cost efficiency [€/t]	8128	8648	18362	
Increase in local renewable energy production [MWh]	12,3	11,6	5,4	14 MWh

2.4 Business models and exploitation

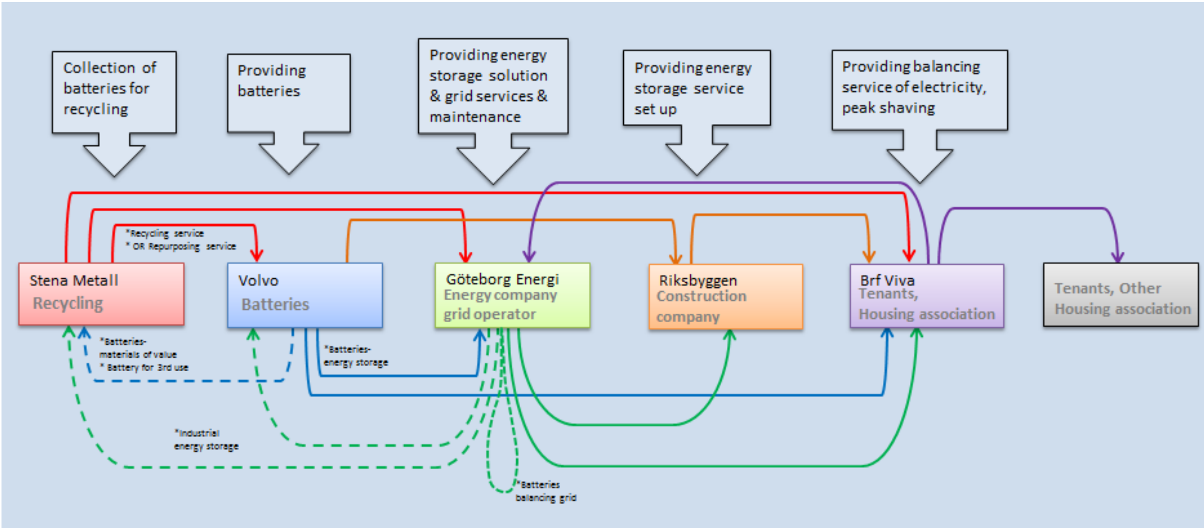


Figure 6. Relations between organisations and services, relating to the second life bus batteries.

- The evaluation of the concept of second life batteries from electrical buses as energy storage in brf Viva is ongoing. Business models of the value chain from battery supplier to the end user to the recycling are developed together with key stakeholders (Figure 6) and one specific model is used in the demo. Together with this a pre study has been made for a further developed concept planned to be replicated in at least one other housing association in Gothenburg, one existing building that is retrofitting its roof and one new development. The further developed concept includes frequency regulation at two different Swedish markets (one that didn´t exist when IRIS started). Another improvement to reach bankability is a standardized container instead of a permanent installation to reduce the investment cost and increase the flexibility. The concept is predicted to reach the market in 2-4 years when the volume of second life batteries is sufficient. The ongoing electrification of several sectors together with the increased share of renewables is also expected to increase the profit of the concept in the coming years.
- All new development from Riksbyggen, all new housing buildings, are expected to have PVs now. This was not the case when Viva was being planned, and although many other tests and demonstrators have shown the operability of PVs, Viva was a project that many in leading positions in Riksbyggen followed closely, thereby learning a lot.
- Energy management systems in building automation is something that will be developed further, both in Viva and in many other projects.

2.5 Lessons learned and next steps

Problems noted in the operation of the batteries related heavily to the integration between the batteries / Volvo's and Ferroamp’s / Viva's control system.

- Alarm management and ongoing operation was insufficient, resulting in discontinuous operations for parts of the system.
- Coordination between actors and distribution of responsibilities could have been better defined.

- Many interfaces, between the technical layers of the batteries, proved surprisingly difficult to integrate, also with the EMS.

Lessons learned:

- Have a "maintenance charging strategy", to ensure that a higher lowest level of charge in the batteries
- Important with continuous operation monitoring, in fine resolution, and act faster on alarms Have a compatible software/control in the batteries from the beginning. E.g. program the batteries for the foreseen second life during first manufacture.

Until the end of the project, the most important remaining steps are to:

Finalize the coolant pipe connection. Make it operational and optimized in every conceivable way. Find and annotate the meters that give data to selected KPIs. Then, study the business models and suitability for replication.

- Find a way to show that the thermal inertia of the building structure provides a benefit as thermal energy storage, thereby improving the energy system.
- Keep improving and developing the EMS/ECO. Involve more subsystems and prove the concept operational in more ways.

3 Preliminary Results of Transition Track 2

KEY MESSAGE

In future energy systems, peak power demands will stand for a large part of operation costs and negative environmental impact. In this transition Track the focus is to how to store energy both electric and thermal cooling energy to reduce the power demand in the energy systems.

In this transition track we focus on demonstration of energy storage in battery systems together with DC systems and energy storage in PCM cooling storage. The location of the demonstrator is shown in Figure 7.

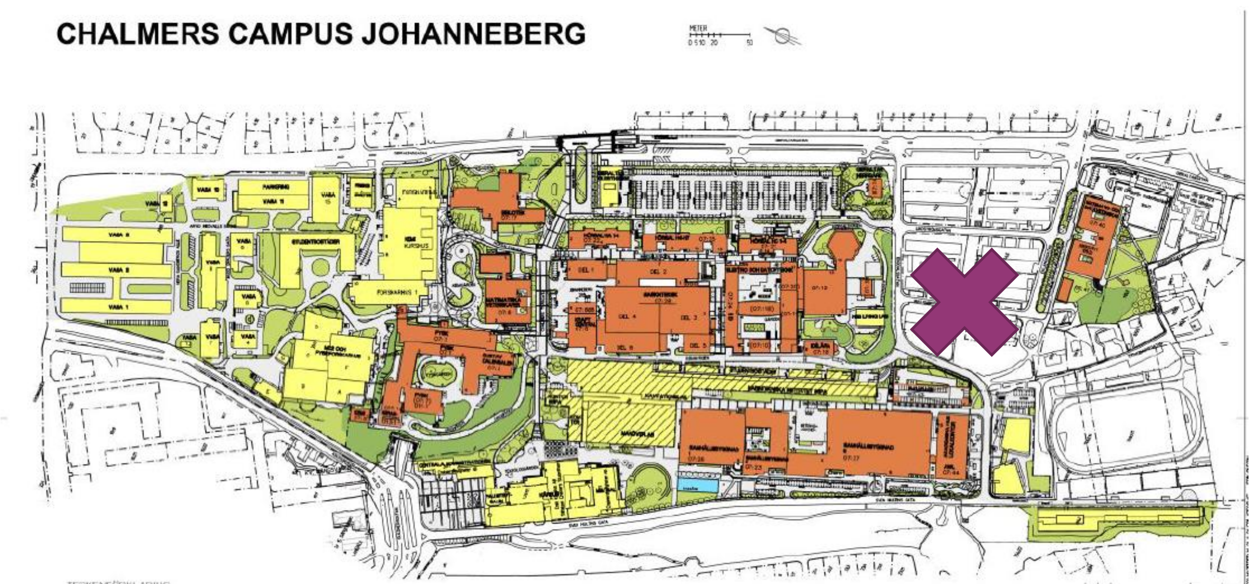


Figure 7. Map of Chalmers campus. Pilot plants are located in building AWL (denoted with "X")

3.1 Demonstrator 1: Demonstration of a 760v DC building microgrid utilizing 171 kW rooftop PV installation and 200 kWh battery storage

Overview

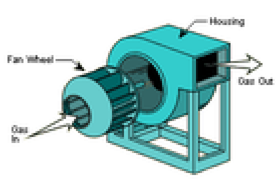
Figure 8. Exterior of AWL building on Chalmers campus

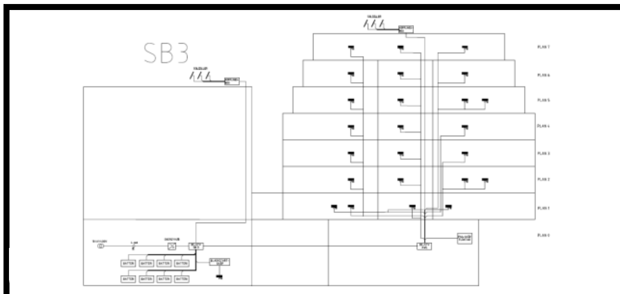
As an attempt to reduce the energy losses in combined solar PV-systems and battery energy storages a DC connected system was proposed. To further reduce conversion stages (and thus electrical losses) between AC and DC quantities, common in multiple appliances within ordinary electrical loads, some loads were connected directly to the DC system. Prior to this demonstration, this was not common practice. Hence, in conventional systems solar power would be converted to AC prior to being fed to the electrical loads and the building. In this pilot system however, lighting fixtures and ventilation fans are connected to the DC-link instead. This in combination with a DC connected battery allows for an improved usage of the produced solar power within the A Working Lab (AWL) building (Figure 8) Furthermore, the purpose of the pilot system was to;

- Contribute to technology development.
- Contribute to line of business' knowledge on DC systems.
- Contribute to research

A brief description of the DC-system can be observed below in Table 8.

Table 8. DC system components and description

	Description
	Main AC/DC converter, responsible for converting power not used by battery or internal DC-loads. And to supply loads and battery when no PV power produced.
	177 kWp solar controlled by 32 optimizers sectioned on 2 different roof tops.
	200 kWh/96kW Li-ion battery ($LiFePo_4$) connected to the DC side of the main AC/DC converter to allow for increased self-consumption of PV, peak shaving, and active power support to AC-grid.
 	DC-connected loads, 1300 lighting fixtures and 20 large ventilation fans in AWL. 20 – 50 kW power consumption depending on temperature, occupancy, and solar irradiance.

	DC-switchgear and cable system, running in parallel to an existing AC system. DC connection points on every floor for possible expansion and for DC-connected lighting fixtures described above.

Time schedule

- **2017** Start of innovation platform for AWL building and decision to bring in the pilot demonstration of a 760V DC building microgrid utilizing 171 kW rooftop PV installation and 200 kW battery storage
- **2017/2018** Design and development of the system
- **2018/2019** Building the system
- **2019/2021** Testing system
- **2021** In operation and KPI measurement

Implementations

The system was constructed by Akademiska Hus, where information and knowledge were shared during the construction in a dedicated project group, called the DC-group. This group contained representatives from Akademsika Hus, Research Institutes of Sweden (RISE), Ramboll, ÅF (currently AFRY), SP-gruppen. The different parties had various tasks closest to their competence area, some listed below in Table 9.

Table 9. Distribution of tasks in the PV/DC team

DC-group members		
Company	**Type of actor**	**Tasks**
Akademiska hus	Real-estate owner	Project lead and project owner, coordinator, meeting leader, main contact towards the company.
SP-Gruppen	Electrical installation	Responsible for electrical installations, project managers of the build, assistance on PV-installation and quotes from providers during procurement writing.
Research Institutes of Sweden (RISE)	Research institute	Expert assignments, sizing of energy storage, loss estimation, power electronics, DC-systems, detailed vendor contacts regarding DC-systems, research projects, master thesis workers, system modelling, technical questions during procurement proceedings.
Ramboll	Electrical consultants	System electrical schematics, protection and fuses, electrical layout.
ÅF (now AFRY)	Energy consultants	PV generation modelling, load modelling, building certification, innovative ideas, procurement writing.

Preliminary Results

Currently the energy storage is set to store PV and cut peaks in consumption on the AC side and the connected AC/DC converter. An example of this can be seen during the 14:th of May 2021 in Figure 9.

Example operation of the AWL DC-system the 14:th of May 2021., during the daytime the system is storing energy in the battery while discharging it during the evening.

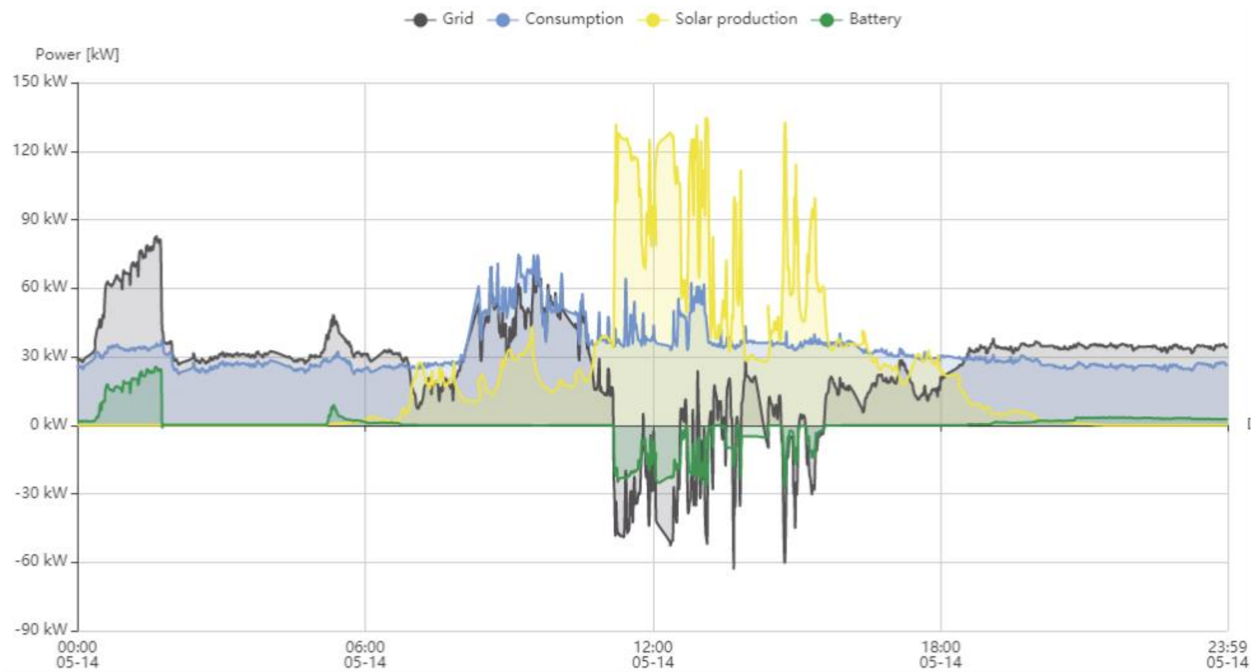


Figure 9. Example operation of the AWL DC-system the 14:th of May 2021.

The system is up and running and the follow-up (KPI) of the DC pilot plant takes place today. PV system has to Maj 2021 produced 180 000 kWh at peak power reduction of 100 kW. The battery storage 200 kWh have been in operation and have been charged by the overproduction from PV's and discharged when PV production is lower than the demand. Preliminary results from battery operation are that the batteries to Maj 2021 have been totally charged and discharged so the exporting of electricity from PV to nearby buildings is minimal. The system works well today, and continuous improvements have been made throughout the project period.

Table 10. KPI table for DC microgrid

Parameter(s)	2020		2021							
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	jul	Aug
Electric energy production by RES [kWh/month]	3343	2590	2583	3695	11317	26647	22228	26846	26074	21378
Electric energy consumption [kWh/month]	37375	36403	36164	34730	37281	41076	39233	41283	44556	42281
Peak power [kW]	83	105	115	110	80	30	25	25	25	40
Peak power baseline [kW]	113	120	130	130	140	140	145	135	125	130
Storage capacity installed [kWh]	200									

KPIs	2020		2021								Target
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	jul	Aug	
Degree of energy self-supply by RES [%]	9%	7%	7%	11%	30%	65%	57%	65%	59%	51%	10%
Peak Load reduction [%]	27%	13%	12%	15%	43%	79%	83%	81%	80%	69%	80% peak power reduction
Storage Capacity Installed	200										200 kWh

Business models and exploitation

Barriers

As always with new technology, there is a level of uncertainty. Some solutions may prove more difficult than planned and results may not be as expected.
There is a barrier in the work finding the right ways for the DC/PV (solar cells) and battery storage constructions. It's also hard to obtain reference facilities that can provide support in the design. Under the period has the development of dc and battery system has been intense. Problem with several electrical components, such as electric heating element for hot water, have caused these to be

disconnected. Another problem is to find dc fans I the market. It has taken a long time because of the difficulties to get the supplier to bring in the dc product in their production. It is a problem to find DC products that normally is driven by AC. The control system for controlling between battery, solar cell and dc systems has taken time to get in place. Problem with control signal interference have made installations difficult.

Market – Target market

The market is the global market for DC systems. In Sweden and at Akademiska hus the DC products can be proposed in future renovations and new constructions within Akademiska Hus project portfolio.

Market – Competitors

To reach the market is rather difficult. There are many systems that are already optimized and the building sector is difficult to adapt to new developments. Suppliers are in the process of launching many different technical solutions.
This includes not only the reluctance to launch new products, but also the price surcharges imposed by wholesalers and vendors. These ensure that the product is no longer attractive to the buyer in the end.

Likewise, one must prove to the buyers that it works. Suppliers must have more pilot test and can then scale the data. However, there are very few DC systems in operation that have good monitoring. Therefore, data of the Chalmers IRIS DC system is important.

Akademiska Hus's business model is to rent out appropriate premises to their tenants, (higher education institutes) in Sweden. This includes proving the building with efficient energy systems. These systems can also act as test equipment for Akademiska Hus's customers. The DC project is a good example of this.

DC systems strengths compared to similar solutions

The DC system strengths compared to normal AC systems are the better efficiency between PV and battery system and also to DC products. On the other hand, the DC system is significantly more expansive today. If the market for DC system and components grows in the future the costs will go down. AC system will always be there, but DC systems will probably sometimes be competitive.

Lessons learned and next steps

Lessons Learned are summarised in Table 11Table 11.

Table 11. Learnings and issues from the DC-system in AWL

Learnings and issues	
DC-project group	Extremely spread of competences that meet in a project with high complexity that needs to work to literary keep the lights on.
Lack of standards	AC-systems has a lot of standards that does not necessarily translate to DC-systems.
Find the right people	It is sometimes hard to find the right person within a company in innovative projects, the DC-project group found most use of the R&D units within various companies. Sales staff could say yes and no to questions with little or no knowledge

	supporting it. This could imply that a supplier left a positive reply whether their component would be suitable, but in the end retract that statement and a new product had to be found.
The procurement of energy storage	How to compare different storage solutions, cycle life, price, capacity, usable range, internal losses, safety etc. The project group proposed several metrics for the providers to supply, as an example lifetime during different C-rates to be able to compare the systems. This was still not easy process.
High DC-system voltage	The chosen DC-voltage by the provider of the AC/DC converter was 380/760 VDC which seemed to be slightly too high for some manufacturers. Perhaps better system design could be reached with lower DC-levels.
Technical issues	Issues related to Black start of the DC-system; the system needs to be energized prior to the connection of the DC-loads. Thus, a DC-ready signal was developed that was sent to the DC-loads. This signal then told the load if it was allowed to start up or not. DC-Balancing of the 380 VDC system to avoid power unbalance on the AC-side; this was made by external circuitry and planning by the 380 VDC loads (lighting loads) to install them in a clever way, not to overload either of the two 360 VDC systems. Such an overload would breach the 1% imbalance requirement set on the AC/DC converter by electrical guidelines.
Unable to remove rectifying stage	Most components had a DC rectifying stage (in order to be used in conventional AC system) that could not be removed. Efficiency improvements were still made, due to higher voltage, but would have been increased if these DC rectifying stages were removed.

3.2 Demonstrator 2: A 200 kWh PCM (Phase Change Material) cooling system

This demonstrator contributes with new knowledge about practical design and real performance of PCM-cold storage. The overall goal of the project was to secure and verify design tools and data to identify a cost-effective and environmentally sound solution of a PCM-TES. A novel, full-scale PCM-cold storage with a phase transition temperature of approximately 11°C has been designed for this purpose and put in use in the AWL-building. For deeper analyses, a smaller (pilot) cold storage tank has been designed for laboratory investigations. Since 2019, storage capacity, power output and utilization rates based on field and laboratory investigations have been systematically studied and presented to various stakeholders, including real-estate owners, HVAC designers, PCM producers, and public. Routines for planning and optimization of charging and discharging cycles have been also developed. Based on the findings, new design process and key performance criteria (KPI) for PCM-TES have been suggested. This report provides insights in the main work tasks and results.

Overview

In today's thermal energy systems, peak power demands stand for a large part of operation costs and negative environmental impact. Various measures can be applied to decrease, or ‘shave’ peak loads, and thermal energy storage (TES) is one of them. Commonly, TES are classified based on physical principles behind the heat storage, which are sensible, latent, and thermochemical. Among these, sensible TES such as water accumulator tanks and ground heat storage are the most common solutions in the heating systems for buildings. After a period of varying interest, latent TES with phase change materials (PCM) have come into the focus because of stricter climate targets and technological developments. Due to a complex technology and high costs, thermochemical TES are yet to emerge for building heating applications.

Thermal energy storage with phase change materials (PCM-TES) are more space-efficient for storing cooling energy above 0°C than traditional water-based TES. During melting and solidification, a large amount of energy is released or stored in a PCM while its temperature changes for about several degrees. In theory, the water-based TES would need to be several times larger than the PCM-TES to store the same amount of energy, within the same temperature range.

When a new building is connected to an existing cooling system, it is generally needed to add new cooling capacity. But if the existing cooling system can produce sufficient cooling when the demand is low, the surplus can be stored in a TES and used during high demand periods. The advantage is also a reduced peak power output.
The expansion of Chalmers Campus Johanneberg area with new buildings will contribute to an increase of power and energy demand in the area. Future energy systems and power loads will be a major part of the energy costs. Reducing power demand is one of the measures to achieve energy-efficient buildings.
The purpose of the PCM Cold Storage connected to AWL building is to is to reduce the peak cooling power demand in the building and, thereby, to avoid new investments in the cooling machinery and high costs for peak power production. Because of a small temperature span for charging and discharging of the cooling energy (2°C), the TES is designed with a PCM rather than with water.

Despite a large interest for PCM-TES in the research community, just a few PCM cold storage systems can be found in real operation. Therefore, a pilot PCM-cold storage has been developed to allow detailed studies on heat transfer processes between PCM and water (heat carrier).

In this demonstration the energy efficiency of the PCM-TES was measured under realistic operation conditions. The efficiency was measured in terms of energy storage capacities, heat loses and investment costs, by having a cooing machine as a reference. The market for PCM product is small today. Therefore, through this demonstration it was tested how the market can deliver needed products and services, and how much effort it takes.

Time schedule

- **2017** Start of innovation platform for AWL building and decision to bring in the pilot demonstration of a PCM cooling storage pilot plant
- **2017/2018** Design and development of the system
- **2018/2019** Building the system
- **2019/2021** Testing system and rebuilds
- In operation and KPI measurement

Implementations

The main drivers for the project implementation were the concept of AWL building as an innovation arena and the innovation-oriented research about PCM-TES at Chalmers. The decision about the innovation track has been made in 2016 by Akademiska Hus in Gothenburg, through the energy engineer Per Löveryd.

Since 2016, the project has been conducted in close cooperation between Akademiska Hus (AH) represented by Per Löveryd, AFRY Gothenburg through energy engineers Kaia Echer and Patrik Lindberg, and Division of Building Technology at Chalmers. The project implementation was aligned with on-going research on PCM-TES at the Division of Building Technology at Chalmers. Between June 2015 - June 2020, Pepe Tan was a PhD student at the Division and the principal investigator under the supervision of Angela Sasic Kalagasidis, professor at the Department of Building Technology and associate professor Pär Johansson.

During 2017, different solutions for the PCM and of the tank design were explored. The final design of the PCM-TES was adopted in October 2017 and project planning documents were made. Construction, installation and running tests were conducted during 2018. From the spring 2019, the full-scale PCM-TES has been in operation.

In parallel, close contacts with German Rubitherm, a manufacturer of the PCM material used in the cooling energy storage in the AWL building were held.

Pilot PCM-TES

The pilot PCM-TES (Figure 10) is installed in the laboratory of the Division of Building Technology at Chalmers (building SB-II) to replicate the full-scale PCM-TES in AWL building. It comprises a transparent container of plexiglass (560 x 560 x 800 mm), heat exchanger, PCM and water as a heat transfer fluid (HTF). The tank is filled with 168 kg salt hydrate with the product name SP11 (Rubitherm), which has the phase transition temperature around 11 °C. The calculated heat storage capacity for this amount of SP11 is 4.92 kWh. The heat exchanger is immersed in the PCM and consists of narrow polypropylene tubes arranged in 18 mats. Each mat has 44 vertical capillary tubes, whereof each 2 are connected in a U-shaped channel. Water circulates through the heat exchanger by means of pumps.

The centre-to-centre distance (cc distance) between the tubes in a mat is 10 mm to ensure a thin layer of the PCM around each pipe and an efficient use of the PCM. The distance between the mats is larger, 25 mm, due to the collector pipes The heat exchanger concept is commercially available under the product name SP.ICE (BEKA).

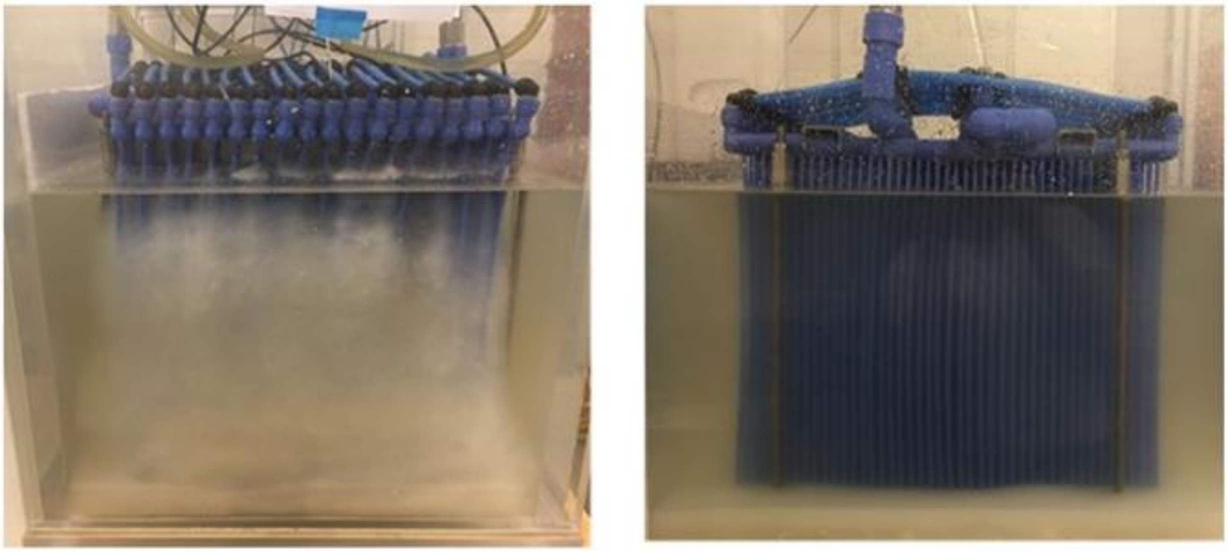


Figure 10. Pilot PCM-TES in the laboratory of the Division of Building Technology, Chalmers. Charged and discharged tank.

Table 12. Pilot PCM-TES – geometry of the tank and properties of PCM

Parameter	Values	Comments
	168 kg	Mass of PCM in the tank
	125,37 L	Volyme of PCM in the tank
	1340 kg/m^3	Density of PCM at 20 °C, based on the producer
	11 °C	Phase change temperature, based on the producer
	25 mm	center-to-center distance between mats
	10 mm	center-to-center-distance between tubes in a mat
	792	Total number of tubes. Each 2 tubes are U-coupled
	18	Total number of mats
	10.5 L	External volume of mats in contact with PCM
V_{TES}	135,87 L	Inner volume of the tank
Q_{max}	4,92 kWh	Calculated maximum energy storage capacity of the tank
	36,21 kWh/m^3	Energy storage density = $\frac{Q_{max}}{V_{TES}}$

Full-scale PCM-TES

The PCM cold storage for AWL building is an upscaled version of the pilot PCM-TES. It has the same phase change material, SP11 (Rubitherm), and the same construction of the heat exchanger. The tank is made of opaque plastic and insulated on the outside.

The tank is placed in the basement of the nearby building called SB-III. It is loaded by the Chalmers campus cooling system through line KB0 and discharged to AWL through KB11 pipe system. Temperature in KB0 system during loading is 7 C. Discharging from the PCM is done at 14 C. Supply and return temperatures in KB11 are 12 °C and 18 °C respectively.

The installed energy storage capacity is 275 kWh according to the PCM manufacturer. After a phase separation of SP11 has been observed during laboratory tests, 3 percent of the superabsorbent polymer (SAP) sodium polyacrylate (FAVOR PAC) was added as a thickener to the PCM, by the PCM supplier.

Figure 11. AWL-building on the Chalmers campus Johanneberg and the PCM-cold storage

The control system of PCM-TES can be accessed remotely by technical personnel at AWL and by Chalmers researchers. This allows various experimentations in real-time. For example, routines for optimization of charging and discharging cycles in respect to the predicted cooling load can be tested. Besides, the control system is set up in such a way to allow virtual (cloud) connections to the smart energy network at the campus, which may lead to further innovations linked to the PCM-TES.

Table 13. Dimensions and energy storage capacity of the full-scale PCM-TES in the AWL building

Parameter	Values	Comments
	9 380 kg	Mass of PCM in the tank
	7 000 l	Volyme of PCM in the tank
	17 200	Total number of tubes. Each 2 tubes are U-coupled
	100	Total number of mats
	481 l	External volume of mats in contact with PCM
	7 862 l	Inner volume of the tank
	2 776 l	Volyme of the insulation around the tank
	11 200 l	External volume of the tank
Q_{max}Qmax	275 kWh	Installed energy storage capacity, based on the producer

Figure 12. A photo showing SB-II, SB-II, AWL, the local cooling plant, and district cooling network

The full-scale PCM-TES has been in operation since the spring of 2019. The pilot tank was actively used during 2019-2020.

Several improvements have been done on the full-scale PCM-TES after it has been put in use. Besides the thickener that has been added to the PCM and additional de-airing of the heat exchanger, several adjustments on the automatic control system have been done. Various control tests have been done after each intervention. Some tests were delayed due to the corona19 pandemic and the weather conditions (too low cooling load). Since 2020, Yichi Zhang, also a PhD student at the Division of Building Technology, is responsible for running the follow-up tests.

As presented in the result section, the declared energy storage capacity and power output from the full-scale PCM-TES have not been reached yet. New meetings will be held with the material producer Rubitherm to discuss the remaining issues. These meetings may result in new devices and implementations.

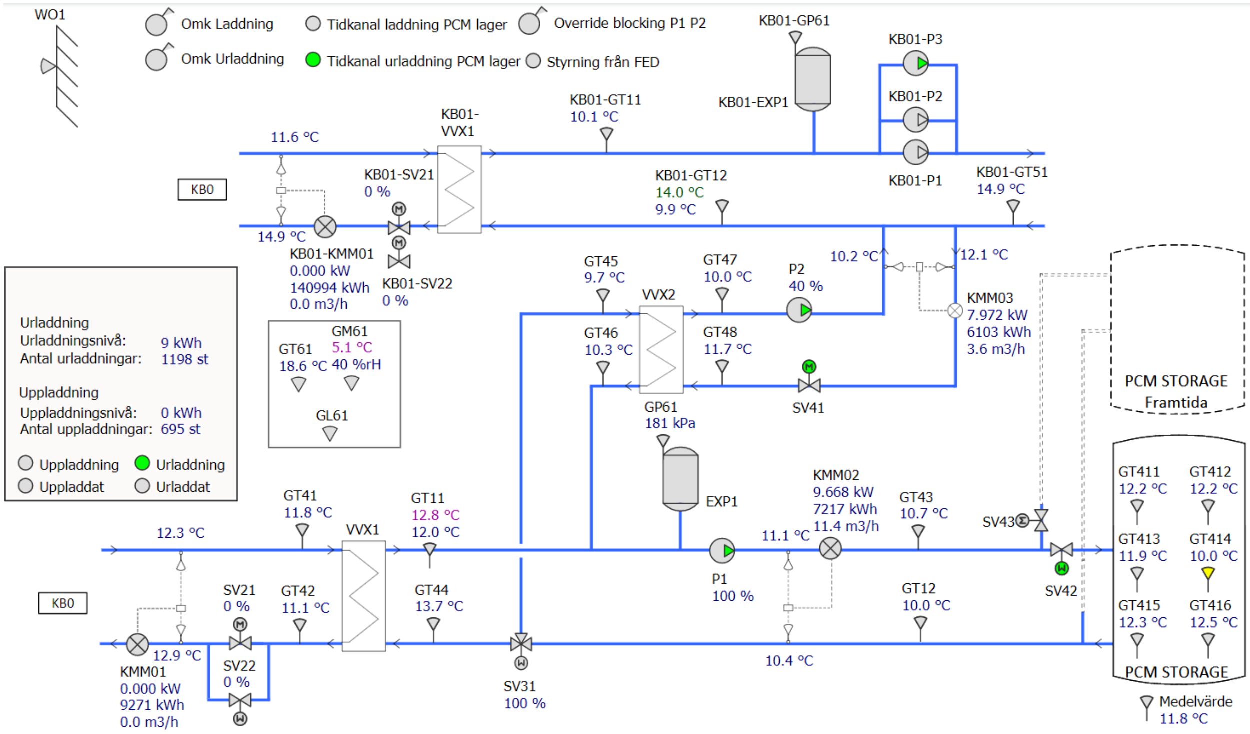


Figure 13. Coupling and control scheme for PCM-TES in relation to the AWL building and the local district cooling network. Operating parameters are taken on March 20, 2021.

Preliminary results

Results of the measurements confirm that the full-scale PCM-TES reduces the cooling demand from the district cooling system. The greatest effects are seen when the discharge starts. As the PCM storage is depleted on energy, the cooling output from the district cooling increases. The discharge lasts for about 5 hours.

However, it turned out that the PCM-TES has a significantly lower charging power and storage capacity than what has been specified by the manufacturer. The charging time is limited to 14-18 hours because the PCM-TES operates as a daily storage. During that time only 36 percent of the theoretical storage capacity was charged, i.e., about 100 kWh instead of 275 kWh. The average charging and discharging power levels were 7.1 - 5.5 kW and 19.8 kW, respectively.

The follow-up (KPI) of the PCM plant takes place today and as mentioned earlier, the plant does not reach the promised power and energy levels. When there is low cooling power load in the cooling system, the power reduction has been up to 9 kW for approx. 5 hours. At high power outputs, the power reduction has been up to 50 kW for approx. 1 hour. Preliminary results are shown in Table X.

At present, it is still unclear why there is such a big difference between the designed and measured energy storage capacity of the PCM-TES. During 2020, various operational tests were performed including adjustment of the circulation pumps and the control system, as well as additional de-airing for the heat exchanger. Minor errors were found and fixed. New capacity tests will be conducted during spring 2021 to check if the correction measures have improved the energy storage capacity of the tent.

A practical design tool for PCM-TES has been also developed in the project. With this tool it is possible to evaluate other designs of the heat exchanger inside the PCM-TES, as well as to optimize charging and discharging cycles for one or several PCM-TES. Calculations with this tool has shown that a better utilization of the PCM inside the tank would be achieved if mats with the capillary tubes are placed denser, basically one more mat between two existing. These results indicate that the heat exchanger design is very important for the good utilization of PCM, and that the current design has potential to be improved. The latter is achieved by placing an additional mat with the capillary tubes between the existing mat. Bars (Figure 14) show how the energy storage density changes when different volumes are used as reference, ranging from the total volume of the PCM to the total exterior volume of the tank

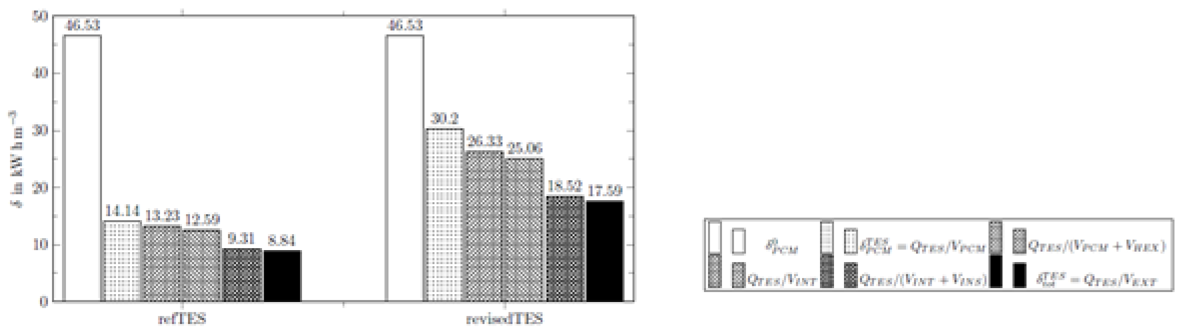


Figure 14. Energy storage density of the PCM volume inside the tank for the existing (to the left) and revised TES (to the right). The latter is achieved by placing an additional mat with the capillary tubes between the existing mat.

Figure 15 below show how peak cooling demands can be shaved in an optimal manner, if two PCM-TES work in parallel. During a warm summer day, the peak cooling demands are cut between 10 – 17 h. If the heat exchangers in both PCM-tanks are revised as suggested earlier, larger peak shaving can be achieved. These results are calculated by the design tool.

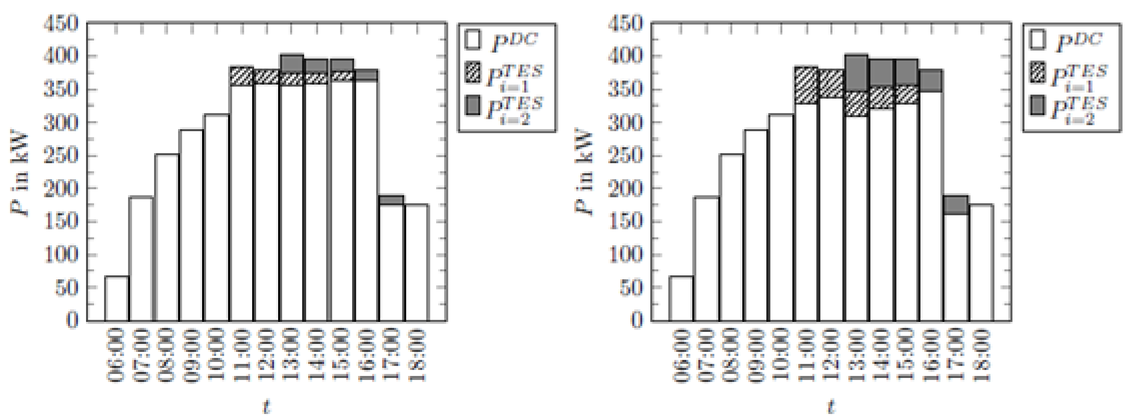


Figure 15. Optimal use of doubled PCM-TES

A cost-benefit analysis of the PCM-TES has been also performed. The purpose of the PCM-TES was to complement the capacity of the local cooling plant, composed of absorption chillers and heat pumps. The

local energy producer has different prices for electricity for these types of cooling machinery. In addition, Akademiska Hus pays a monthly maximum power fee to the utility company which is based on the month's highest power peak consumed.
With the existing PCM-TES, a total cost reduction of approximately 4,2 percent can be achieved. The largest cost savings (Table 14) results from the decrease of the peak electric power surcharge, and not so much due to the variable electricity price between charging and discharging. The calculations assume a payback period of 5 years. If the energy storage capacity is increased, by adding e.g. another PCM-TES, larger cost-savings can be achieved.

Based on the financial results, a limit on investment costs can be defined as a key performance indicator (KPI) for a predetermined payback period. Investment costs for the PCM-TES in the AWL building were SEK 546 452, of which 64.5 % or SEK 352 462 was the cost for the PCM, 13.9 % for the tank and heat exchanger and the rest was for transport and installation. These costs are much higher than the calculated limit for investment costs.

Table 14. Cost saving for cooling without and with PCM-TES

Case	Cost saving for power, %	Cost saving for energy, %	Total cost saving, %	Investment limit (SEK) for 5 years payback time
Current PCM-TES	-8,19	-0,76	-4,17	9 804
Revised PCM-TES	-13,03	-1,08	-6,55	15 421
2 x current PCM-TES	-15,10	-1,42	-7,68	18 075
2 x revised PCM-TES	-22,84	-2,06	-11,58	27 235

It is worth noting that the financial results are usually case-dependent and that other assumptions may lead to different conclusions. Therefore, the future work should focus on finding applications where a PCM-TES is profitable. Compared to water-based TES, it may be necessary to express a potentially high energy storage density of PCM-TES into an additional economic benefit, such as saving floor space. A PCM-TES can also be more profitable compared to purchasing new cooling machines. For a correct evaluation, a more accurate LCC analysis is needed. More information on PCM-TES durability and maintenance costs should be available from the manufacturer.

Because PCM-TESs in full operations are rare, there was an intensive collaboration between Akademiska Hus, Afry, Chalmers, and various subcontractors during the design, installation, and testing of the PCM-TES. These collaborations were important knowledge-enhancing activities for all involved partners, implying that innovations projects should be run in this or similar collaboration between the industry and academia. A rather large interested of the public has been received. Multiple interviews for national technical magazines and public seminars were given. Inquiries by interested representatives from industry and academia were also received, but many have been postponed due to the corona19 pandemic. Several scientific articles with the results from both the pilot and full-scale PCM-TES were published in collaboration.

Table 15. KPI's for PCM storage demonstrator

Parameter(s)	2020		2021							
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Peak power [kW]	9	9	9	9	8	8	90	101	222	58
Peak power baseline [KW]	9	9	9	9	17	26	125	136	257	93
Storage capacity installed [kWh]	100									
Energy output [kWh] (from PCM)	500	583	532	587	1050	1635	1482	788	742	149
Energy input [kWh] (to PCM)	600	870	739	771	1348	2010	1781	841	445	215

KPIs	2020		2021								Target
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
Peak Load reduction	0%	0%	0%	0%	53%	69%	28%	26%	14%	38%	
Storage Capacity Installed	100										Target for step 1: 200 kWh/50 kW for 4 h Target for step 1+2: 800 kWh/150 kW for 4 h
Storage energy losses	17%	33%	28%	24%	22%	19%	17%	6%	-67%	31%	

Business models and exploitation

Barriers

Cooling system can produce cooling to a storage when demand is low in the system, the stored cool can be used in high demand periods. The advantage is also a reduced peak power output from the cooling machine.

If there is a need for more cooling and more cooling production and you use PCM as a cooling storage solution, you can use your existing cooling equipment to manage the increased need for cooling.

The market for PCM cooling storage will probably increase as the demand of being able to produce cold when the price is low. Through the PCM cooling storage the cold production can be optimized after the **energy price.**

"Market" – Target market
The market is the global market for refrigerated products. In Sweden and in Akademiska hus the PCM products can be proposed in future renovations and new constructions within Akademiska hus project portfolio.
"Market" - Competitors
To reach the market is rather difficult. There are many systems that are already optimized, and the building sector is difficult to adapt to new developments. Suppliers are in the process of launching many different technical cooling solutions.
This includes not only the reluctance to launch new products, but also the price surcharges imposed by wholesalers and vendors. These ensure that the product is no longer attractive to the buyer in the end.
Likewise, one must prove to the buyers that it works. Suppliers must have and test storage and can scale the data. However, there are very few storage devices that have good monitoring. Therefore, data of the Chalmers IRIS PCM storage is important.
PCM strengths compared to similar solutions
To store cold can be done through several technical solutions depending on what temperature that should be delivered. The strengths of the PCM cold storage compared to other cold storage techniques is that the PCM is compact compared to alternative water volume storage and that it can deliver a more stable temperature.

Lessons learned and next steps

- Collaboration between industry and academia in true innovation projects like this one is needed and beneficial for both partners
- A combination of a pilot and a full-scale TES is recommended when there is a lack of expert knowledge and design references
- PCM-TES can be used for shaving of peak cooling demands
- Producers of PCMs need better methods for the characterization of their products, PCMs
- Design of the heat exchanger shall be improved to increase the utilization of the PCM

4 Preliminary Results of Transition Track 3

The MaaS concept EC2B offers customers an attractive alternative to owning/using a private car, allowing easy access to a variety of transport modes (e.g. e-cars, e-bikes and public transport) in connection to where customers live or work. The two demonstrators in T7.5 (Housing association Viva and Campus Johanneberg) are up and running as planned, even though the Covid-19 pandemic and the restrictions implemented due to it has meant that usage of the EC2B service for employees in demonstrator #2 has been low

The key findings of the two demonstrators implemented within the IRIS project are:

- The EC2B service is appreciated among users
- The demonstrators have spurred a large interest, not least among property companies, as EC2B is unique in connecting MaaS to real estate
- The business model has shown to be replicable, with several new projects being implemented during the last years, also on commercial terms
- As expected from other similar pilots, one of the main barriers to be overcome concerns the technical integration of many different mobility services into one app
- Especially in demonstrator #2, EC2B for employees in the campus area, the complex structure with several property owners, employers and mobility service providers has proved to be a challenge, requiring time and energy to coordinate the interests of all parties involved.

4.1 Overview

In T7.5, a new Mobility as a Service (MaaS) concept called EC2B ("Easy to be" or "Easy to B"), has been implemented in Gothenburg in two different contexts. In demonstrator #1 EC2B is implemented for residents in the 132 apartments in housing association Brf Viva in Gothenburg, where no private car parking is available. In demonstrator #2, the EC2B concept is adjusted to cater for the needs of employees in the campus area of Johanneberg. See Figure 16 for the location.

Figure 16 Photo of demonstration area with Johanneberg campus area in the centre and BRF Viva to the left.

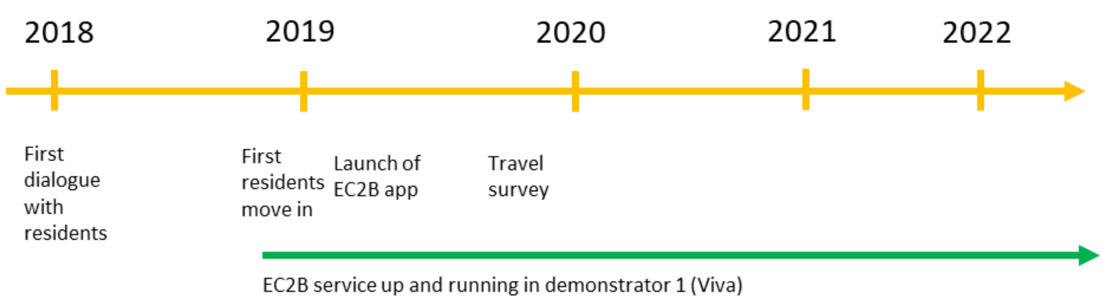


Figure 17 Timeline of demonstrator #1, EC2B in Housing association Viva

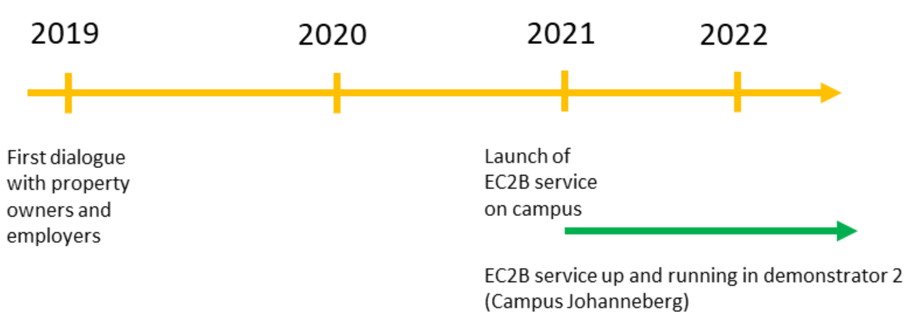


Figure 18 Timeline of demonstrator #2, EC2B on Campus Johanneberg

4.2 Implementations

Demonstrator #1, EC2B in Housing association Viva

Figure 19 Housing Association Viva in Gothenburg, view from the south. Shared e-cars can be spotted under the green roof adjacent to the middle building.

Demonstrator #1 was implemented from December 2018 (Figure 17) when the first residents moved in, although preparatory dialogue was initiated more than a year earlier. Residents in Brf Viva have access to three (initially four) e-cars, Renault Zoe (Figure 19). Residents also have access to three electric cargo bikes and four e-bikes, as well as charging infrastructure for all types of electric vehicles (55 recharging polls for e-bikes, 6 for e-cars and 2 for light e-vehicles) (Figure 20). During a trial, a light e-vehicle, "Zbee", was added to the pool of vehicles. The first bikes and cars were installed in December 2018 when the first residents moved in, and the number of cars and bikes were adjusted as more and more residents move in to reach the numbers indicated above. To access the e-bikes and light e-vehicles, an electronic key cabinet has been installed which is opened using the EC2B app.

Figure 20 Shared e-cars to the top left, key cabinet for shared bikes to the top right, and below the bike garage with shared e-bikes, including cargo bikes, to the right down the green lane.

The EC2B app was launched in February 2019. Information activities for residents took place already during the year before they moved in but were intensified during the period when they moved in, with several information gatherings ("mobility evenings") where the mobility services were demonstrated, and residents were offered support to get started using the EC2B service. In October 2019, a travel survey was made among the residents to follow up travel behaviour, use of the EC2B service and user satisfaction. The EC2B service is still up and running.

Demonstrator #2, EC2B at Campus Johanneberg

In demonstrator #2 a dialogue with property owners and employers in the Johanneberg campus area was initiated in early 2019 and continued throughout 2020 (Figure 18). The dialogue resulted in a common understanding of how the EC2B service offered in the campus area should be designed to be useful to employers in the area.

Figure 21 To the left sign in the campus area explaining the mobility hub concept and where to find the mobility services included. To the right, shared e-bikes at one of the hubs.

Four mobility hubs (Figure 21) were created in the campus area, combining e-cars, e-bikes, and public transport, and the EC2B service, integrating these transport modes within one app, was launched in November 2020. Figure 22 Figure 22 below presents a map of the hubs. Due to the Covid-19 pandemic and restrictions and recommendations of working from home, avoiding physical meetings, and avoiding the use of public transport, usage of the service has so far been very low. The service will be in use at least until the end of September 2021, but discussions are going on about a prolongation until end of 2021. There is an agreement among the property owners in the area to continue a collaboration on common mobility services. At the very least, the mobility hubs will become permanent.

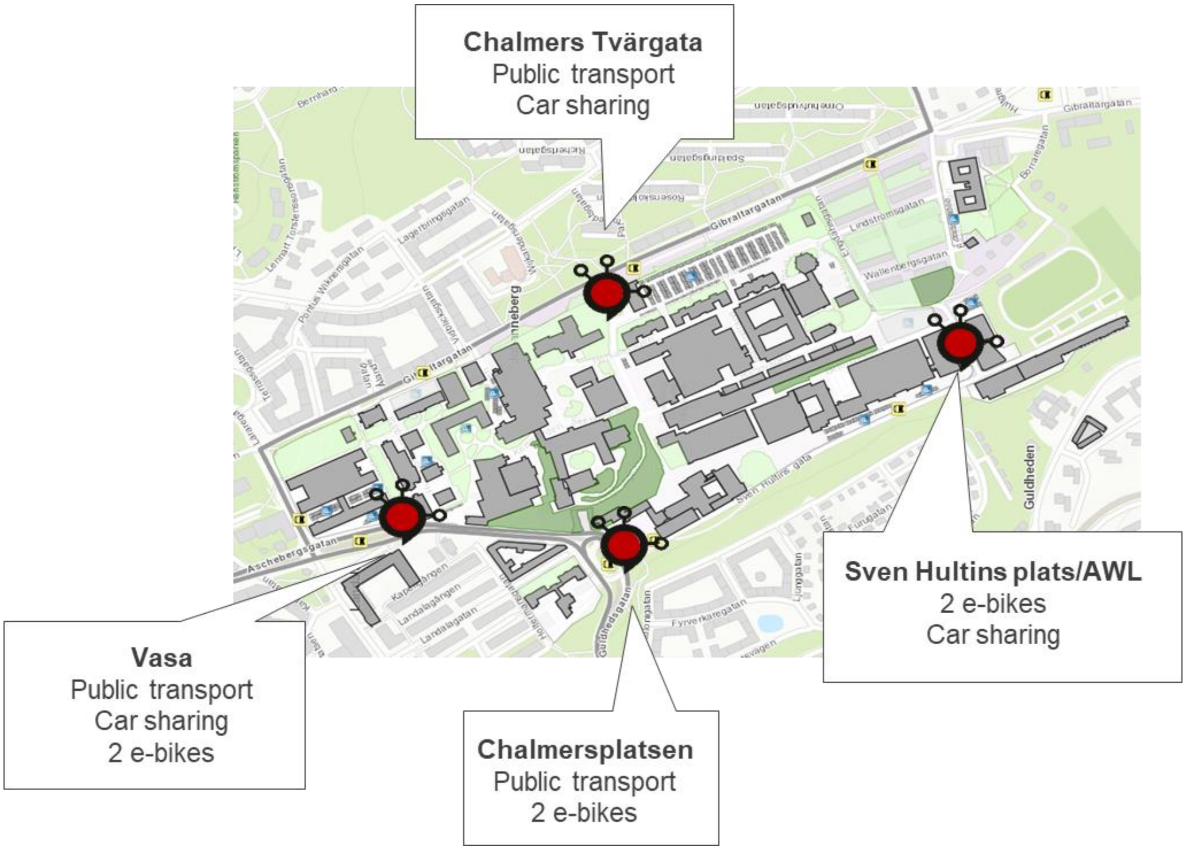


Figure 22 Map of mobility hubs in Campus Johanneberg

4.3 Preliminary results

Demonstrator #1, EC2B in Viva

When it comes to end-users' experiences, we know most about demonstrator #1, as it was up and running well before the pandemic.

The use of mobility services in Viva is high compared to "ordinary" housing projects with only shared cars. The use of the shared cars started faster than car sharing provider Sunfleet had normally expected and the occupancy of the vehicles has been relatively good, with many bookings also from users who do not live in Viva themselves. The shared e-bikes have also been much appreciated and used by the residents, possibly partly because booking the bikes initially was free.

Experience has shown, however, that heavy use also means relatively large running costs to keep the bicycles in good condition, which needs to be budgeted for.

Purchasing public transport tickets in the EC2B app was popular during a trial when the tickets were discounted, but when the discount disappeared, most people switched back to buying tickets in the public transport company's app. It's obviously difficult to compete with the original.

An overview of number of bookings of the services included is found in Figure 23 below.

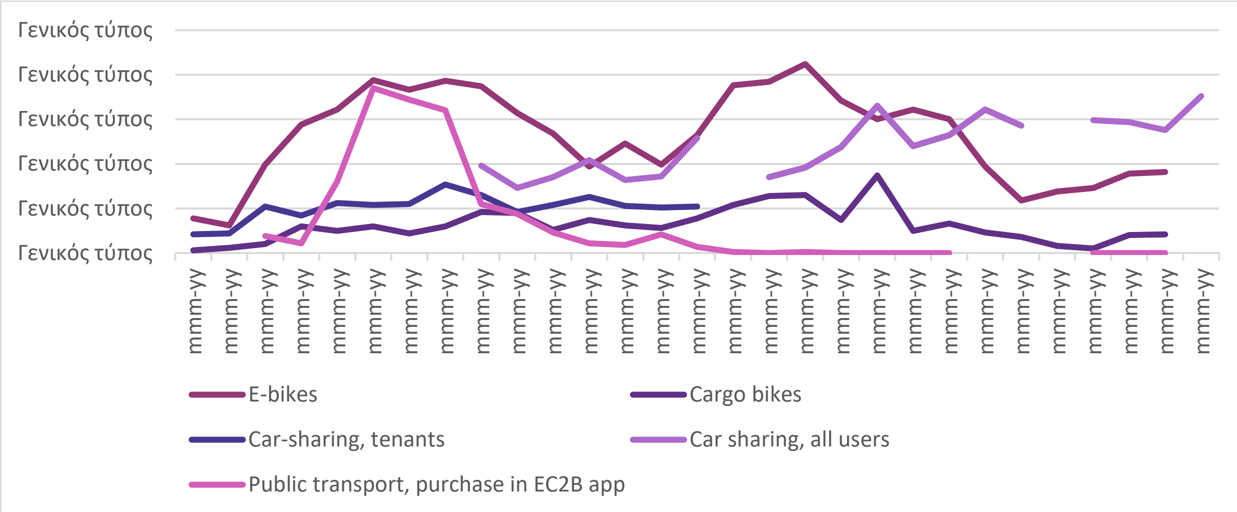


Figure 23 Viva mobility services, number of bookings/month

Overall, the results show that the EC2B service is appreciated by users, see Figure 24 below.

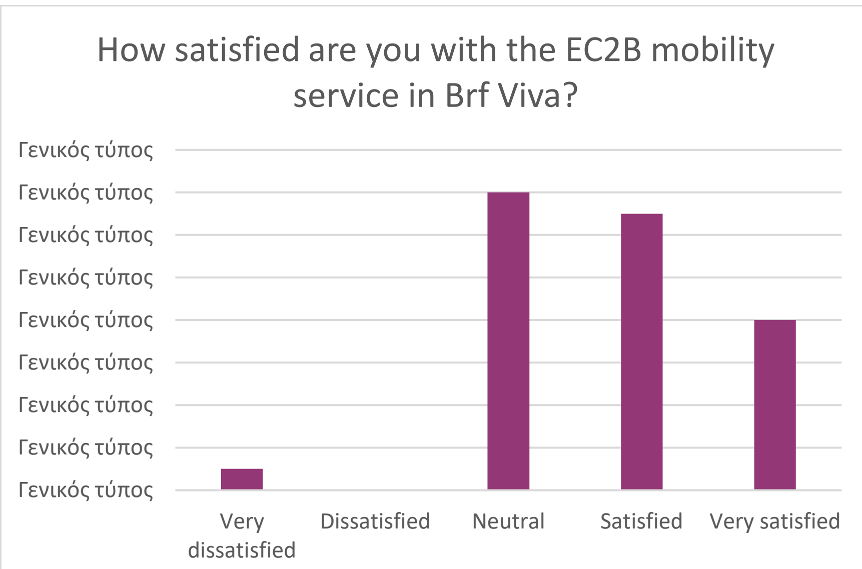


Figure 24 User satisfaction in Brf Viva, after one year of trial

Our results show that many of the residents in Viva used to own a car but got rid of it in connection with moving into Viva. One group travelled sustainably already before and was attracted to Viva due to its sustainability profile. At the same time, quite a few have kept their car and arranged a parking space in the surrounding area. However, car ownership is significantly lower than the average for Gothenburg. A total of 32 cars are registered on inhabitants in Viva, while the expected number of cars (based on an average for the area, which is already relatively low compared to other parts of the city) would be 68 cars. Also the number of kilometres driven has been substantially reduced: The average for Gothenburg is 6 470 km/person and year, while the inhabitants in Viva drive in average 3 500 km/person and year. As shown in Figure 24, the level of satisfaction with the service is very high.

Demonstrator #2, EC2B at Campus Johanneberg

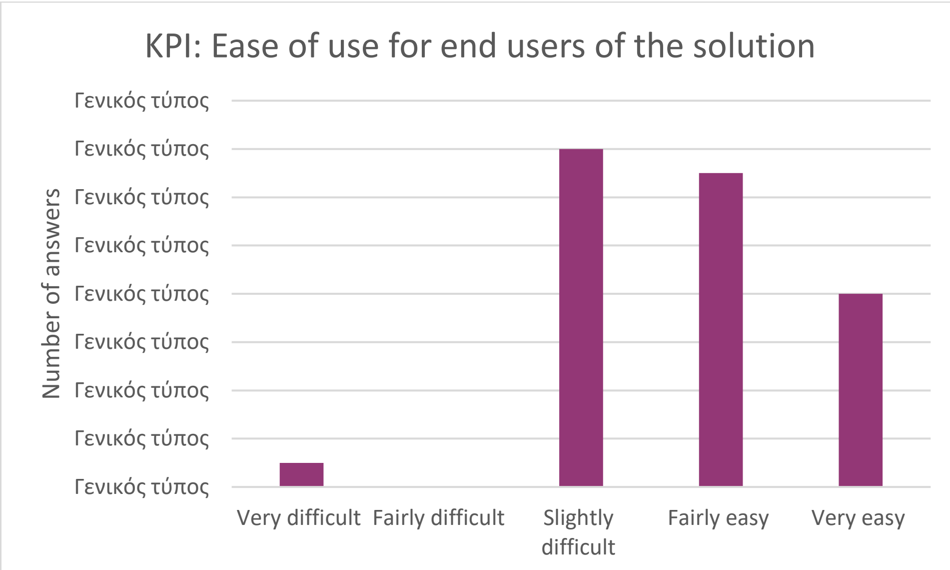
End-users' experiences from demonstrator #2 have not yet been fully evaluated. It is difficult to get validated results since there have been few users and few trips. So far, comments have been made about the great potential of the concept once it is fully operative, but also that the positive experience decreases rapidly if there are any problems with some part of the service.

Table 16. KPI Table for mobility services

Parameter(s)	2018	2019	2020
Km driven by tenants before implementing the measure (km/year)	1106370		
Km driven by tenants in conventional cars after implementation (km/year)		569430	
the CO2 coefficient for conventional vehical (t CO2/km)	0,0001205		
the CO2 coefficient for electrical vehical (t CO2/km)	0		
number of cars owned before moving to the demonstration area	68		
number of cars owned after moving to the demonstration area		32	32
Km driven by tenants after implementing the measure (km/year)		598500	
Km driven in e-car sharing system after implementation (km/year)		29070	
Very difficult (number of answers)	1		
Fairly difficult (number of answers)	0		
Slightly difficult (number of answers)	14		
Fairly easy (number of answers)	13		
Very easy (number of answers)	8		

KPI	2019	2020	2021	GA- Target
Carbon dioxide Emission Reduction (ton/year)	64,7			1040 tonnes reduction in 5 years
Reduction in car ownership among tenants	36	36		
Reduction in driven km by tenants (km)	507870			1360500 km/year car mile reduction among tenants and employees in the

				district for measure 3.1 and 3.2
Yearly km driven in e-car sharing systems	29070			



Stakeholder experiences have been evaluated more in detail and property owners and employer organisations have drawn some conclusions based on their experience of the demonstration. Many stakeholders connected to the campus area would prefer to set up a mobility broker solution in the long run, similar to the concept demonstrated in the project, but they are also highlighting some obstacles. One obstacle is that there are too few suppliers available that can handle the role as a mobility broker. Another obstacle identified is the difficulties to design a public procurement for such purpose. The demonstration has so far provided valuable experience especially regarding the complexity of the demonstrated service. A preliminary result is that the stakeholders at campus see the benefits of working together to set up mobility services for business trips.

Regarding the KPIs (Table 16), the ex-ante survey among end users indicates that less than 50 % of the respondents were satisfied with their mobility solution before they tried the demonstration. The most common reason to participate in the demonstration was curiosity. Bike sharing is by far the most popular service, but it is hard to draw any conclusions due to the restrictions caused by the pandemic that affect the potential for especially public transport (avoid, few business trips) and car sharing (few business trips).

4.4 Business models and exploitation

The main value propositions of EC2B are formulated in the following way:

- EC2B helps residents in the (larger) cities to travel sustainably without the need of owning a car. This is done through the packaging of flexible mobility services, counselling, and a community for sharing.

- EC2B helps real estate developers who want to offer the market a modern, urban, and low-car housing concept, through a package solution for sustainable and flexible mobility that is attractive to both customers (residents) and authorities (the municipality).
- EC2B helps mobility service providers who want to reach a large and affluent market for their sustainable mobility services. It will form part of a comprehensive service for sustainable mobility, easily available at home.
- EC2B helps cities create a more attractive urban environment and sustainable development with fewer cars and a significantly more efficient land use, as well as significantly reduced climate impact.

EC2B helps real estate actors meet municipal requirements of low-parking housing concepts through packaging different mobility services into one mobility concept which is made available to end users through the EC2B app. The real estate actor pays EC2B to set up the services, provide the EC2B app to users during a pre-defined time span, and arrange on-boarding activities to get users started, while mobility service providers get paid as their services are used. Compared to building an expensive garage to meet parking requirements, the cost of setting up and running EC2B is significantly lower for the developer.

The business model of EC2B has been tested in two different varieties within the two demonstrators of T7.5. While both concern integrating mobility services with the built environment, the set-up when it comes to the actors involved differs slightly. With EC2B for workplaces, the additional layer of the employer is added between the property owner and the end user. In demonstrator #2, the fact that several property owners active in the campus area needed to collaborate added further complexity.

However, the EC2B service has been replicated in several different contexts since the first implementation in Brf Viva, and the start-up EC2B Mobility has been set up as a daughter company to Trivector to further develop the business model and scale up the service. So far, the EC2B service has been replicated in Lund and Västra Frölunda. The Xplorion project in Lund is similar to Brf Viva as it also a new housing project with zero parking lots. In Västra Frölunda, the EC2B service has been implemented in an existing building complex in collaboration with the municipal housing agency Framtiden, who wish to reduce the number of parking lots in an existing area to be able to use the land to build new apartments.

4.5 Lessons learned and next steps

The combination of good access to mobility services and tailored information activities has made the residents feel satisfied with their mobility situation despite the fact that there is no residential parking in Brf Viva. However, car ownership is still far from zero.

Nevertheless, the fact that those who still own a car are forced to park some distance from home has led to a sharp decrease in car travel. The residents in Viva travel more sustainably than they did before, and more sustainably than the average Gothenburg citizen. Data also shows that it is not only the residents of Brf Viva who have benefited from the mobility services, but the shared cars are used extensively also by residents in the surrounding area.

Car-free or low-car housing can make a significant contribution to sustainable transport, but it is important to have reasonable expectations of the first pilot projects. For even greater effect, more coordinated mobility measures and mobility services are needed. As of today, all mobility services are not yet fully integrated in the EC2B app, and the on-boarding process to get access to all the services included is more complicated than what is ideal. An even more supportive traffic environment in the immediate area, such as higher parking fees at nearby car parks, would also be clearly desirable to further reduce car ownership among residents. So far, it has turned out to be quite easy, and not very expensive, for residents to hire a parking lot in the surrounding area, which of course reduces their incentive to sell the car and start using the EC2B service.

From a stake-holder perspective, an important conclusion is that mobility as a service is not just more services, but what gives increased potential is coordination, packaging and holistic thinking. How can public transport create offers that are relevant for MaaS users, in combination with other services? What can be done to make the on-boarding process easier? What services need to be included to create an offer that covers all types of needs that users might have? But this coordination and packaging does not happen by itself. Since mobility as a service is new for everyone - residents and users, real estate actors, municipalities, mobility service providers, technology providers, etc. - no one can fall back on how you “usually” do things. New solutions need to be tried out. Herein lies the challenge of being able to realize the great potential that exists in mobility as a service for real estate. Here is an important role for the city / municipality to play, who set the rules for this type of solutions, integrating mobility with housing or workplaces.

For the remaining demonstration period, we hope that the pandemic situation will allow us to see an increased usage of the EC2B service at Campus Johanneberg, to be able to collect more data from the end-users. We will also collect new data on car ownership in Housing cooperative Viva, to see how this develops over time. Most importantly, we are now having discussions with several new real estate partners with whom we plan to replicate and scale up the EC2B service in many new contexts.

5 Preliminary Results of Transition Track 4

In Gothenburg the IRIS project has demonstrated two different solutions in TT#4:

a. The CIM pilot project which is an implementation of tools for collecting and sharing of data from building projects with support by FIWARE components. The main collected data is BIM data – Building Information data.

b. The Energycloud have been implemented and is a local version of a cloud for collection data within the energy system. The local system has been delimited to three universities and their Landlords in the Gothenburg region.

5.1 CIM- City Information Model pilot

5.1.1 Overview

CIM can be compared with the concept BIM, Building Information Model, used in the building process. A BIM model is a 3D model of the building where all the information about the building is collected and organised though the buildings life. CIM could be described as BIM for an entire city. The theory that was tested in the demonstrator CIM pilot in T7.6, is that if the City starts collecting BIM data from all its buildings, the City will eventually build up a CIM. The CIM pilot in T7.6 is therefore a pilot implementation of tools to collect and share data from building projects, BIM data. The pilot has been tested with data from the reference project "Hisingen bridge" (Figure 25, Figure 26) thus it is implemented in the area where the Hisingen bridge is built in Gothenburg.

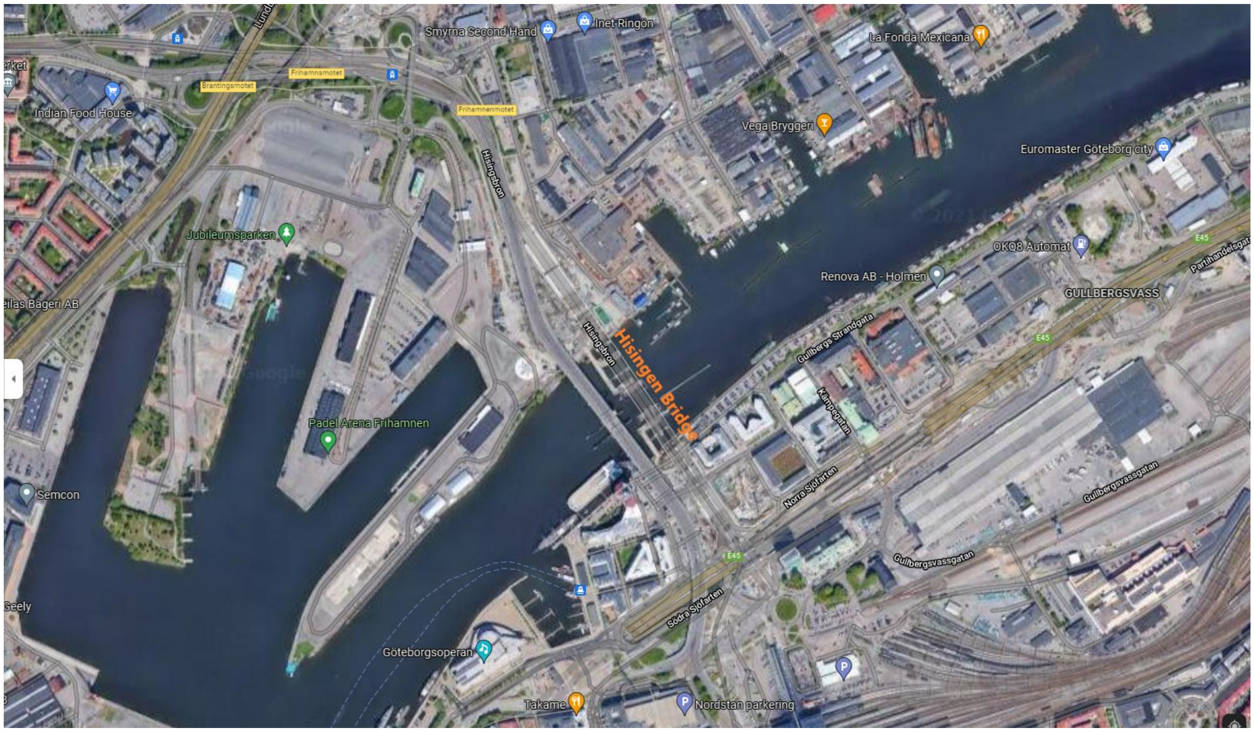


Figure 25: Map showing the area around the new Hisingen Bridge.

Figure 26: An image from the visualisation of the Hisingen Bridge

The CIM pilot was ready for demonstration and evaluation Q1 2020.

From the start the plan was to have an innovation challenge based on the data in the CIM pilot. During the project it has become evident that an innovation challenge based on the CIM pilot would not have given much value, so instead of doing that activity, we documented our experiences in a report, see Annex 2. The main reason for cancelling the innovation challenge was the lack of building data to share due to confidentiality. This was a problem that we had not foreseen but nevertheless an important insight. This is addressed in chapter 5.1.9.

5.1.2 Implementations

The implementations in the CIM pilot are based upon infrastructure data as the pilot has been developed for the Urban Transport Authority, in the City of Gothenburg.

It is implemented from two use cases: ***Visualize your City*** and ***Kick start your project***

The use case ***Visualize your City's*** main objective is to give citizens and users an easier way to access/acknowledge projects and means to influence the planning process. The objective for the use-case ***Kickstart your project*** is to give design teams an easier way to access and reuse data relevant for their projects and thereby simplifying the design process and making it more cost effective.

To achieve the objectives of these use-cases the following implementations have been done:

- A specification of **BIM requirements**: A first version of a specification of BIM requirements usable for infrastructure projects in a city.
- The **BIM Data Collection Tool**: A pilot version of a tool that can be used by the city to collect, validate and save project data (BIM data) that follow the BIM requirements specification.
- A **test version of a CIP** based on FIWARE technology, where the project data is saved and from where the data could be downloaded from or accessed through APIs. The data in the CIP is described in a data catalogue (**CIM Data Catalogue**). The CIP also have a web-based interface where project data is listed and can be searched. Through this interface the data can be downloaded (**CIM Data Retrieval Tool**).
- An API specification over the APIs to access the project data programmatically
- **CIM Visualization Tool** is a simple test tool to test the possibilities to visualize project data uploaded to the test CIP and accessed through the API.
-

5.1.3 Specification of BIM requirements

From a sustainability point of view this task has focused on information sustainability.

The most sustainable information is in fact the re-used information.

Even if we may not always realize this, the collection, production, and handling of information require resources and therefore also adds to the total footprint.

We have identified the interface between projects and asset management as the weak point where information most often is lost.

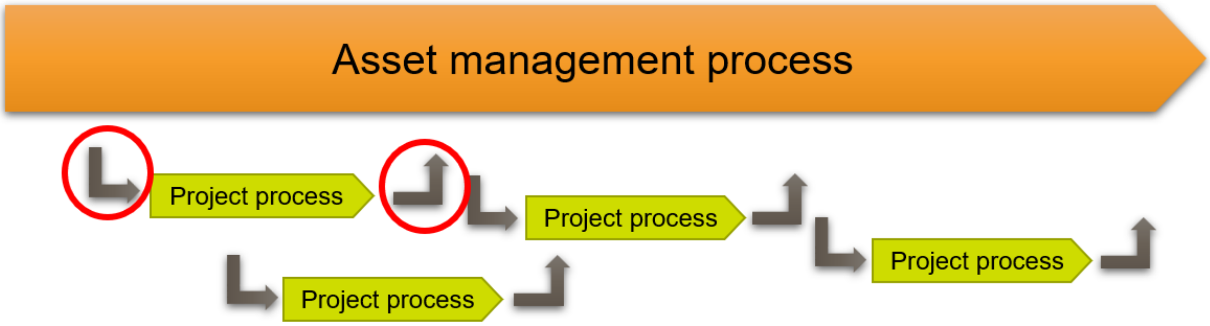


Figure 27: Asset management infinite process docking with projects. Information exchange points identified as weak points.

The purpose of the BIM requirements is to specify the interface between the Asset management process (Figure 27) and the Project processes. The requirements are governed by the Asset management process. The BIM requirements will make it clear to the project groups what to expect in terms of information from the Asset management process and what it must give back when the project is finished. The BIM requirement delivery specifications also exist in a machine-readable format to facilitate automatic validation as described in chapter 2.2.2

If all infrastructure projects follow the same requirements the project data can more easily be saved, shared, searched, and reused. For example in the document" Riktlinje Digitala leveranser för förvaltning" published by BIM Alliance, the organizations Akademiska Hus AB, Fortifikationsverket, Riksdagsförvaltningen, Specialfastigheter Sverige AB and Statens fastighetsverk, have concluded that common clear requirements will lead to a more effective information handling regarding building information.

The BIM requirements specify down to object detail how to classify and set attributes. The rulesets are divided into disciplines (i.e Roads, Railroads, Geotechnics)

The classification part of the BIM requirements is based on the Nordic CoClass standard, which is also used by the State Road Authority in Sweden for infrastructure buildings. The specification of requirements are described in the document "BIM-kravTK_v1_0". CoClass is from the beginning based on the SS-ISO 12006-2:2015 standard describing general classification for the built environment.

5.1.4 BIM Data Collection Tool

The BIM data Collection Tool (Figure 28) has been designed to automate and validate the import process from Project into the Asset management database. It is based on the delivery specification set out in the BIM requirements. The BIM Data Collection Tool is used by the Design Teams to upload project data to the city Asset management database. The BIM Data Collection Tool has a web interface where projects can deliver infrastructure project data to the Urban Transport Administration. It is implemented as an FME sequence of operations and utilizes the scripting capabilities of FME to interpret and validate input files of building or construction work. The input data must comply to the BIM requirements. Files are uploaded as zipped packages of files in .ifc or .dwg format. The FME processes provide both evaluation documentation, processing logs and converted 3D object data files in CityGML format out of the CAD files and sends these objects to the 3DCityDB in the test CIP for separate storage. Original files are also stored in a CKAN dataset.

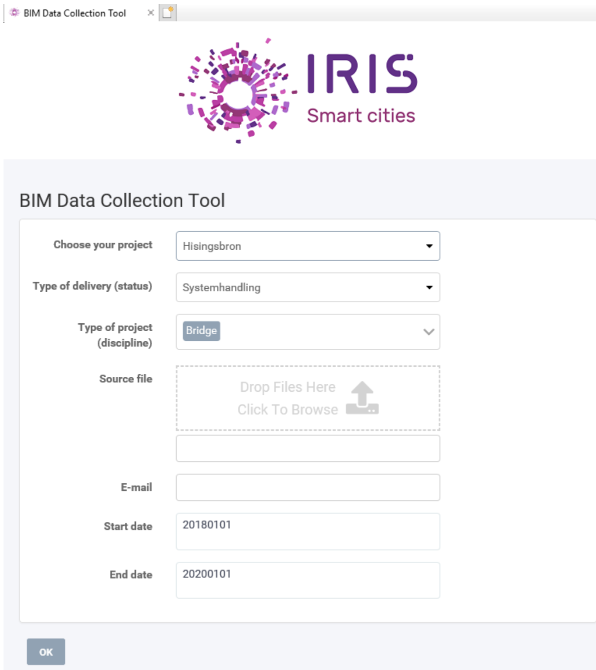


Figure 28: The web-based interface of the BIM Data Collection Tool

5.1.5 CIP test version for CIM pilot

The test version of CIP was developed to support the use cases of the CIM pilot only. It was based on the reference architecture described in D4.2 and the technical solution reference architecture described in D4.4. It uses a mixture of Fiware and other open software or internally developed components. The system is set up in a Docker environment with several containers. Read more about this in Deliverable 4.6.

The CIP have a web-based interface where project data is listed and can be searched, this is a styled standard CKAN web interface. Through this interface the data can be downloaded. The user can search for datasets and resources by bounding geography in an interactive map control, use buttons for the most utilized tags or keywords, select datasets by an organization or search for any dataset descriptive text content.

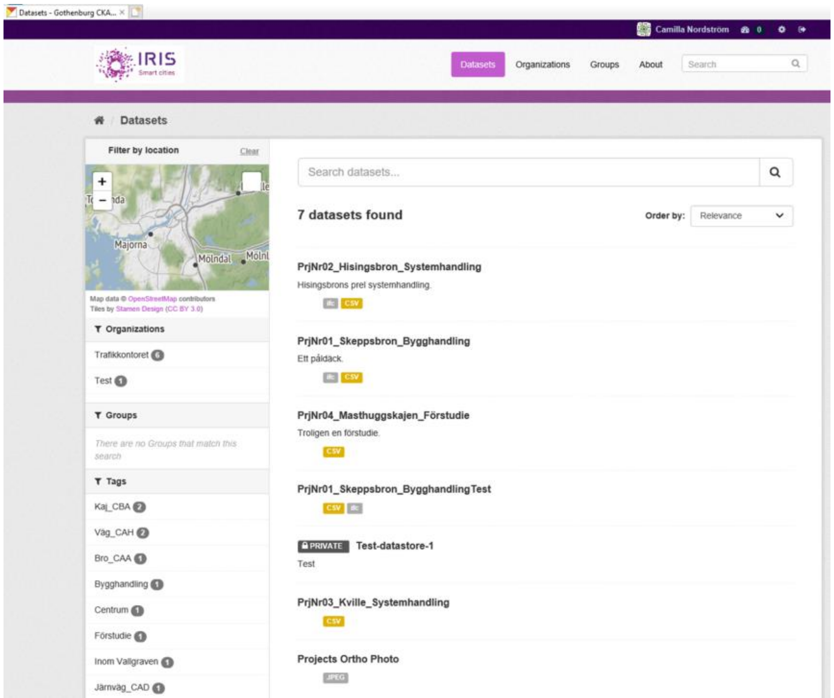


Figure 29. CIM Data Retrieval Tool

5.1.6 API specification

The API specification is a document that describes the interfaces to be used for input of data into the databases of the CIP as well as the interfaces, tools and access conditions for management and retrieval of data. The main part of the document is focused on how to access the data through API's, mainly the CKAN API and the 3DCityDB Importer/Exporter API, see the document "CIP Pilot API description TK Gbg".

5.1.7 CIM Visualization Tool

The tool is a simple visualization tool to visualize the data available in the CIM. The purpose is to test access and use of the CIM data available through the available APIs (Figure 30).

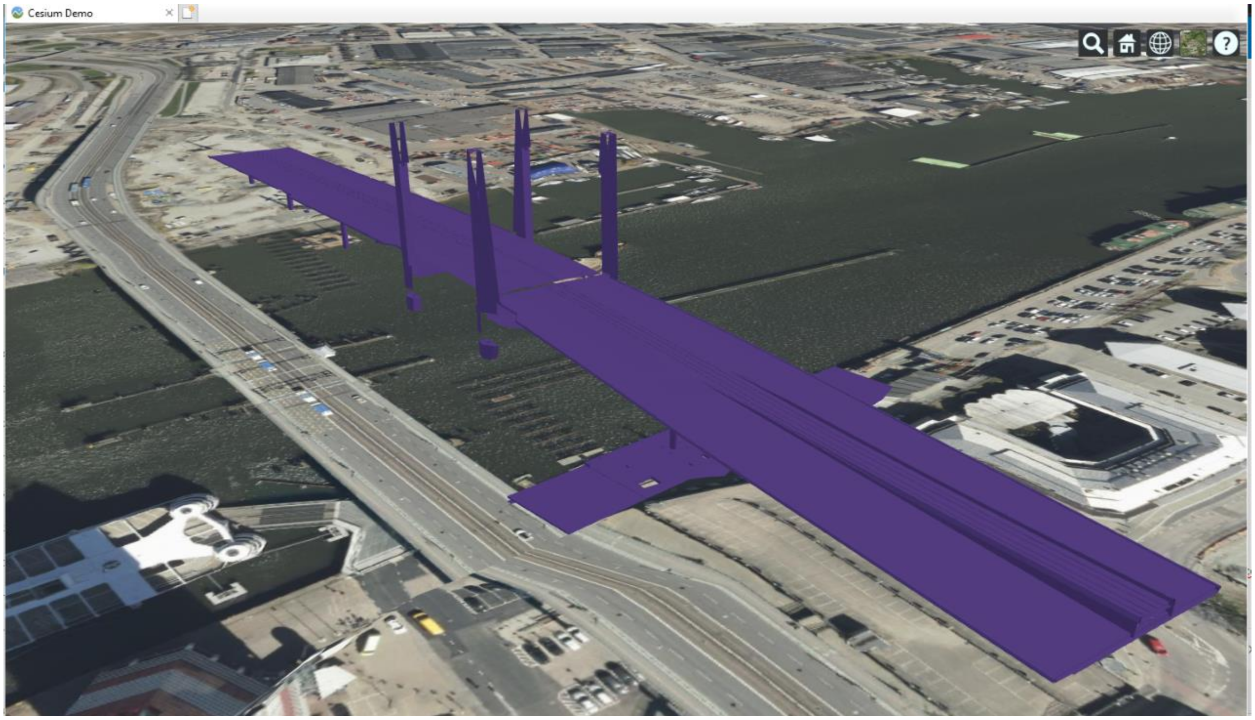


Figure 30. CIM Visualization Tool

5.1.8 Implementations CIM pilot, general comments

The CIM pilot is a test, and it has not reached the desired level so that it can be used for real, since the barriers for that are too high (see chapter 5.1.9). Because of this there are currently no decided plans on how to proceed with implementation of the CIM pilot. But, for the city, tools to collect, validate and save BIM data from projects, are highly needed, so it is most likely that those tools will be implemented, in some way, first.

The City of Gothenburg is investigating how to implement CIP and doing tests based on FIWARE. The CIP will most likely not have building data to start with, but other more available datasets. Currently the City is testing water temperature and soil moist level measurements. These datasets will be published via the CIP as a part of the test. Other datasets may be published via the CIP during the test period.

5.1.9 Preliminary results

High barriers for implementing the CIM pilot

The barriers for implementing the CIM according to the ambition initiated for the CIM pilot are very high:

Availability of BIM data:

There is not as much useable project data as we expected available. The city has not had any guidelines regarding how 3D data should be provided, so the structure of the data available are currently different for each project, which makes it hard to put in a common database. BIM requirements, like the ones produced in this project needs to be in place in order to start collecting BIM data in a structured way. These requirements will only affect the projects purchased after the requirements are in place so to build up a reasonable amount of project data in the CIM will take many years.

Sharing of BIM data:

The city has a hesitation on sharing this type of detailed data in such an easily accessible way. At first, we did not think that sharing official BIM data would be a problem or a risk, however as the project has shown how easily this BIM data could be accessed and used, the risks of malicious use also have become more evident. There is a fear that the data could be used in the wrong way. Especially for types of projects that are considered sensitive for security reasons. We have also discovered that for some projects, project data cannot be shared due to procurement reasons. Cities have barriers in sharing the data and unfortunately there are no guidelines or requirements for collecting and sharing data and therefore the processes do not move forward. There is a hesitation, and no one is willing to take the step to move further. The data is available but is only intended for use by the project. Thus, the data needs to be classed in the models so that it can be shared in the right way. The city needs to review how the digital models can be used in other phases of the project and in other parts of the administration.

These barriers have also forced the City to not go through with the planned Innovation Challenge, which was originally part of the scope of the project. The purpose of the Innovation Challenge was to encourage the usage of the shared BIM data in useful applications. But as we could not share enough interesting project information, there was no purpose in going through with the innovation challenge, as the usefulness was expected to be very low compared to the effort needed for the Innovation Challenge. Reed more about this in Annex 2.

5.1.10 User evaluation

The CIM pilot has been evaluated by the personnel at the Urban Transport Authority (UTA). The evaluation was done in a workshop where the users responded to questions in the meeting. There were three people evaluating the CIM pilot. Two persons work with technical management of assets and one of the persons is a design project manager. The design project manager also took the role as a data supplier in the evaluation as he has recently worked in design teams in the private sector. The results from the evaluation are the following:

The BIM Data Collection tool and specification of BIM requirements

In general, the evaluators see a great value with more common, clear requirements that each project can reuse and a tool where you can deliver data from projects and that validates the data. They would highly appreciate if the UTA continues to work for an introduction of BIM requirements and a tool that validates deliveries of BIM data towards these requirements. They believe that this can facilitate the work for both management of technical assets and the project work. Management of technical assets points out that the validation part would be very valuable for them. The project management concludes that it would be easier to avoid "inventing the wheel" before each project when deciding what requirements to set. The project management also sees values in being able to share 3D models with each other between projects, especially in areas such as the Central Area, and everyone is served by getting updated information about what is going on.

The delivery requirements as such are not considered to be completely easy to understand. It could be because no one has really worked with such or with CoClass. The project management believes that most likely, the consultants who are supposed to deliver the data, will understand the delivery requirements. Management of technical assets are uncertain whether the requirements are sufficient from the perspective that the UTA is a plant owner. More details are probably needed.

The user interface of the data delivery tool is perceived by everyone as very user-friendly and easy to understand. One point of view is that you might be able to use the tool for other deliveries other than what is intended according to the pilot, for example delivery of review documents. The results of the validation were perceived as a little difficult to understand by project management but again it is believed that a consultant working in this field will understand the error codes.

Project management believes that consultants would appreciate delivering data through a simpler portal like the BIM data collection tool unless they must deliver the data elsewhere as well. It must not be too different to deliver according to the requirements, in relation to how the project work with the BIM models internally in the project. If the requirements are included from the beginning, when signing the contract, it makes it easier.

CIM data collection tool (the web-based user interface of the CIP)

In general, it is believed that this type of tool, when only containing data from the different stages of projects, would primarily facilitate the work at the UTA.

Asset management find an advantage in being able to refer people to a portal to retrieve information instead of having to look up data themselves.

Project management think it will be useful to be able to retrieve the data yourself, compared to having to find the correct persons to ask. Finding the latest data from a project's stage will facilitate when shifting stages in a project. But it is possible that an external consultant, wants to get the information from his client and may not want to download it himself from a portal. External consultants probably need more details. For example, it will not be enough to know that the construction time is from start to finish. The main benefit of the portal for projects are in the analysis and the planning phase and not so much during the implementation and completion phase of a project.

Project management sees potential in a tool like CIP being able to reduce costs and facilitate collaborations but believes the impact will be limited if the information is too general.

It is considered relatively easy to search and find data in CIP, but that may be because there is not much data. There are suggestions for improvements in the search function. Metadata about the files per project is needed.

One suggested improvement would be if you could choose to subscribe to certain projects or partial deliveries.

For future realization

Major considerations that have emerged in the user evaluation that needs to be addressed for future realization:

- how long should the models/data be saved and maintained after the construction stage
- versioning of documents
- digital maturity of all parties needs to be high enough for this to work
- level of detail, so that it does not become too general and provides the desired benefit
- how to ensure that everything is delivered as required even towards the end of the projects
- ensure that delivery requirements meet asset management needs
- user rights for consultants to retrieve data through CIP

Suggested improvements:

- ensure that the delivery requirements and validation results are more understandable
- ensure that the metadata description of the files is included in the delivery package and that the description is visible in CIP
- introduce a viewer to the data contained in CIP

introduce a subscription service linked to the tool, to know when documents uploaded

- multiple files should be able to be downloaded at the same time from CIP
- Small improvements in search function and also scavenging functionality

5.1.11 Progress on KPI measurement

All the selected KPIs for the CIM pilot have been measured. The results are presented in Table 17 below.

Table 17: Results of measurements of CIM pilot KPIs

KPI	Parameter(s)	Baseline	Target (as described in DoW or declared)	Result
Ease of use for end users of the solution	Ratings on the Likert scale, of “Ease of use for end users”, provided by users [integer, Likert] =78	N/A – The CIM pilot is new	The ambition is that the calculated average rating given by the users should be 4 or more on the Likert scale 1-5, where 5 is very Easy, and 1 is very difficult. (Not in DoW)	4,3 Target reached
	Total number of users that have provided a rating of “Ease of use for end users” [integer]=18			
Advantages for end-users	Ratings on the Likert scale, of “Advantages for end-users”,	N/A – The CIM pilot is new	The ambition is that the calculated average rating given by the users should be 4 or more on the Likert	4,4 Target reached

	provided by users [integer, Likert] =70 Total number of users that have provided a rating of “Advantages for end-users” [integer]= 16		scale 1-5, where 5 is very high advantage, and 1 is no advantage. (Not in DoW)	
Quality of open Data	Number of datasets that are DCAT compliant in CIM pilot [integer] = 7 Total number of datasets in CIM pilot [integer] = 7	0.There is no CIM Pilot and there are no Datasets in the CIM pilot.	100% of DataSets in CIM pilot are DCAT compliant. (Not in DoW)	100% Target reached
Open data-based solutions	Number of applications using the API in the CIM pilot [integer]= 0	0.There is no CIM Pilot API and therefore there are no applications using it.	Number of applications using the API are more than 5.	0* Far below target
Usage of open source software	Number of full purchased solutions from one single company used [integer] = 1 (FME)	0.There is no CIM Pilot and therefor there are no solutions built with or without open source software.	No full purchased solution from one single company is used in the CIM pilot. (Not in DoW)	1** Below target

*The reason no Open Data based solutions based on the CIM pilot have been developed, is that we cannot share the data openly as is explained.

**We have used Open Source software as much as possible, but the FME product was needed to get the solution to work. We could not find any Open Source products that were good enough for the task.

No more KPI measuring is planned for the CIM pilot.

5.1.12 Business models and exploitation

The business model for the CIM pilot is a Societal Business Model. It is described in chapter 5.2.2 in D7.6.

In general, the CIM pilot has potential of creating societal value, as time and money could be saved for the City both when managing building projects and when managing existing buildings. Also, the CIM pilot has the potential to contribute to a more sustainable society as the most sustainable information is the re-used information. To reach the potential, a lot of work and money needs to be invested, and it will take time before the benefits can be harvested. Today it is not certain that the City have the resources required to do these investments in the close future.

5.1.13 Lessons learned and next steps

There is a value and a need for collecting and sharing of BIM data. As investigated, the services demonstrated in the pilot are considered very useful, by the users responding in the user evaluation. However, the barriers for implementing the CIM according to the ambition initiated for the CIM pilot are very high as described earlier. Due to this, no more development is done on the CIM pilot as such for the moment.

But the work continues in other projects and forms:

- The City of Gothenburg sees the advantages with a CIM and the possibilities a complete CIM can provide the city. Work on the CIM began as an activity in the IRIS project but the potential for the future use was evident. Lessons Learned on how to integrate BIM data and on the implementation done of the 3D city database has been transferred from the IRIS CIM pilot project to the CIM project for the whole city.
- The work we have completed in IRIS provides a strong base for the continued work with BIM data. There is an expected value in being able to collect and share BIM data, but the city and UTA does not have much experience or knowledge in working with this type of data. Because of this the city needs resources to raise the knowledge base and continue the journey with BIM. The UTA have applied for more resources to start working with BIM from year 2022, where the first step would most likely be to create plan for how to implement BIM at UTA based on the experiences from the IRIS project.
- The city of Gothenburg has an ambition to create a joint work/platform for CIP. Knowledge and experience from the work developing the test CIP in the CIM pilot is used in this work.
- Digital Twin. In Gothenburg, many initiatives regarding digitalization are being implemented. One goal is to create a digital twin (Figure 31) Figure 31. The City of Gothenburg - Digital Twinof the city. Having a digital copy of the city, connected to real-time data, will facilitate gathering, sharing, and visualizing relevant information in one platform for planning, control and maintenance. The Digital Twin can also serve as a test bed for development and innovation striving to achieve the global sustainable development goals. There is overall a political interest in opening data, because it increases transparency and stimulate innovation. Benefits would be improved planning and greater efficiency in execution, for instance improved logistics when building new houses or infrastructure. The major challenge is to handle security issues and abuse of certain data, which need further development.

Figure 31. The City of Gothenburg - Digital Twin

- In order to develop the concepts of CIM, digital twin and data distribution Gothenburg has deepened its understanding of FIWARE

5.2 EnergyCloud

Key learnings

Quality of data is usually not a topic that is highest on the agenda when starting to collect and present data. It is very common that quality of data is neglected in the beginning of these projects. However, quality of data has shown to be the biggest bottleneck in the EnergyCloud setup within the project. The local Landlords have their own systems and their own way of quality assuring, structuring and naming the data created in the buildings. To unify this and allow tenants within the ecosystem to create their own quality assurance and structure has been the biggest challenge.

Key recommendations

When applying a cloud service with data make sure that energy users can integrate and develop applications individually. The need for reports and visualization of data can change between different actors, regions, and types of buildings. Therefore, flexibility when choosing integrations and applications is very important. This has shown in the local Energy Cloud built within the project and considering all the different stakeholders there would be in applying this into a city then flexibility and ability to choose will be of high importance.

5.2.1 Overview

The transition into a smart energy system is completely reliable on data. Data needs to flow between different actors within the system in a secure and adaptable way. In the smart energy system that is currently being developed there are tenants, utility providers, renewable energy sources industries and other actors and they are all in the need of easy data access (Table 18). Data also needs to be quality assured so that decisions both automated and human decisions are taken based on reliable information.

The project called EnergyCloud has been aiming at creating a local version of this system to show that it is possible to share, and quality assure structured data within the energy system. The local system has been delimited to three universities and their Landlords in the Gothenburg region.

By creating structured clouds of energy data all actors involved, and even entire cities will be able to utilize data in a better way and to create new value propositions. By establishing this first case where data is digitized and shared among interested actors this EnergyCloud project can work as a guiding star for other similar projects throughout Europe.

EnergyCloud has been developed in Gothenburg together with the following partners Metry (EnergyCloud), Akademiska hus, Chalmers Fastigheter (Real Estate Owners), Göteborg Universitet, Chalmers, Högskolan i Skövde (University tenants). The BI consultancy company Business vision has built an application on top of the EnergyCloud platform to illustrate what can be done with structured digitized data (**Fout! Verwijzingsbron niet gevonden.**).

The main activities of the project have been to:

- Set up data collections from Real estate owners
- Validate and quality assure data
- Structure data from Real estate owners
- Share data with university tenants.
- Workshops to get input on external application built by Business vision.
- Follow up on data collection and quality issues.

5.2.2 Implementations

To allow for the benefits with digitized energy data (such as electricity, heat, water and gas) described above Metry has within the project provided a platform where all energy data from the above-mentioned actors has been collected.

Akademiska hus and Chalmers are real estate owners measuring energy data in their buildings. Göteborgs University, Skövde Högskola and Chalmers are in this case tenants that are renting office and educational space from these real estate owners.

The need for data from the tenants (Universities) is based on many usage areas where the most urgent and important one is to report data within a climate initiative signed by almost all Universities in Sweden. This initiative is called the Climate Framework and more information and what Universities that has signed up to this can be found here. Within The Climate Framework it is clearly stipulated that energy data should be followed up on and reported by the Universities on a continuous basis.

This creates a clear need for energy data, data that before this project was stuck with the real estate owners managing the buildings. Below you can see some of the other application areas for data that was identified during the workshops.

Table 18. Application areas for data

Who?	Organisation	Why?
Environmental co-ordinator	University	Environmental reports and sustainability reports creates the need for data on how much energy that has been used divided on different energy-types.
Scientists	University	Basis for scientific work where scientists need real data and real buildings for their projects.
Students	University	Basis for environmental projects and education.
Real estate owners energy controllers	Compare sustainability work and energy consumption between different universities and campus.	Raw data exports and CO2-equivalents
Environmental institutes	Other	General information about environmental impact from external actors. Raw data exports and CO2-equivalents

Politicians	Other	Use data to understand the current status and take high level decisions. Raw data exports and CO2-equivalents
Journalists	Other	Use data for reporting. Raw data exports and CO2-equivalents.

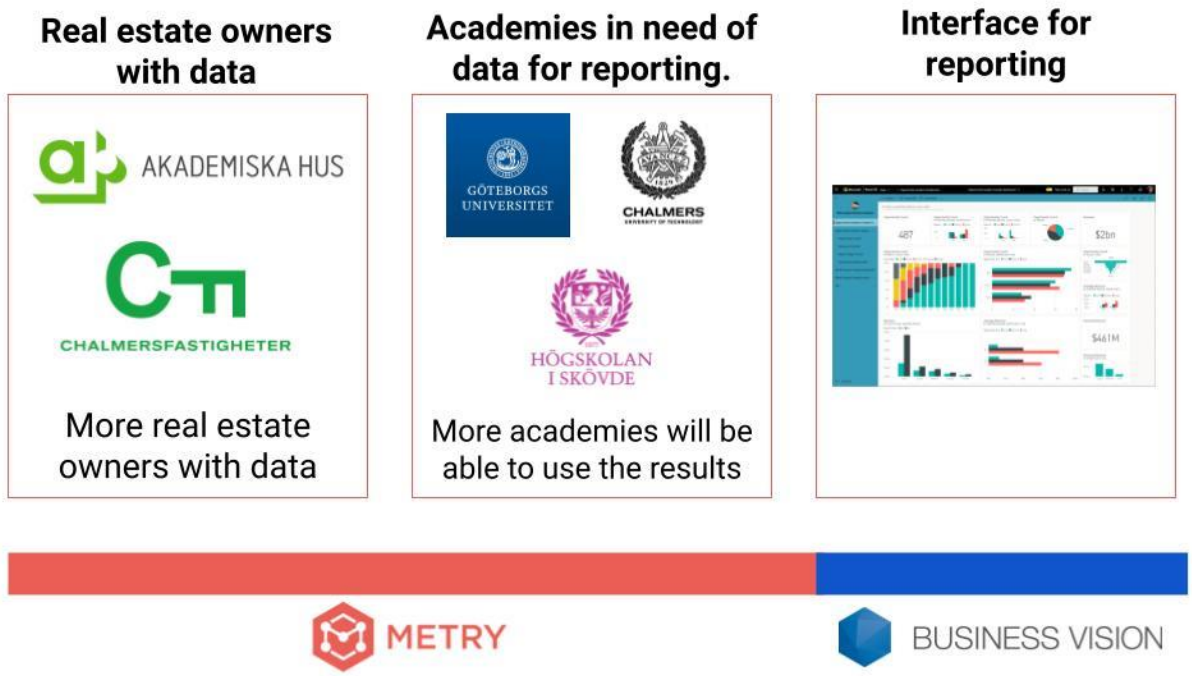


Figure 32 Stakeholder map for the Energy Cloud

Based on the need to report energy data the actors within the project have set up an EnergyCloud of data with the purpose to structure and share data to the tenants Universities renting.

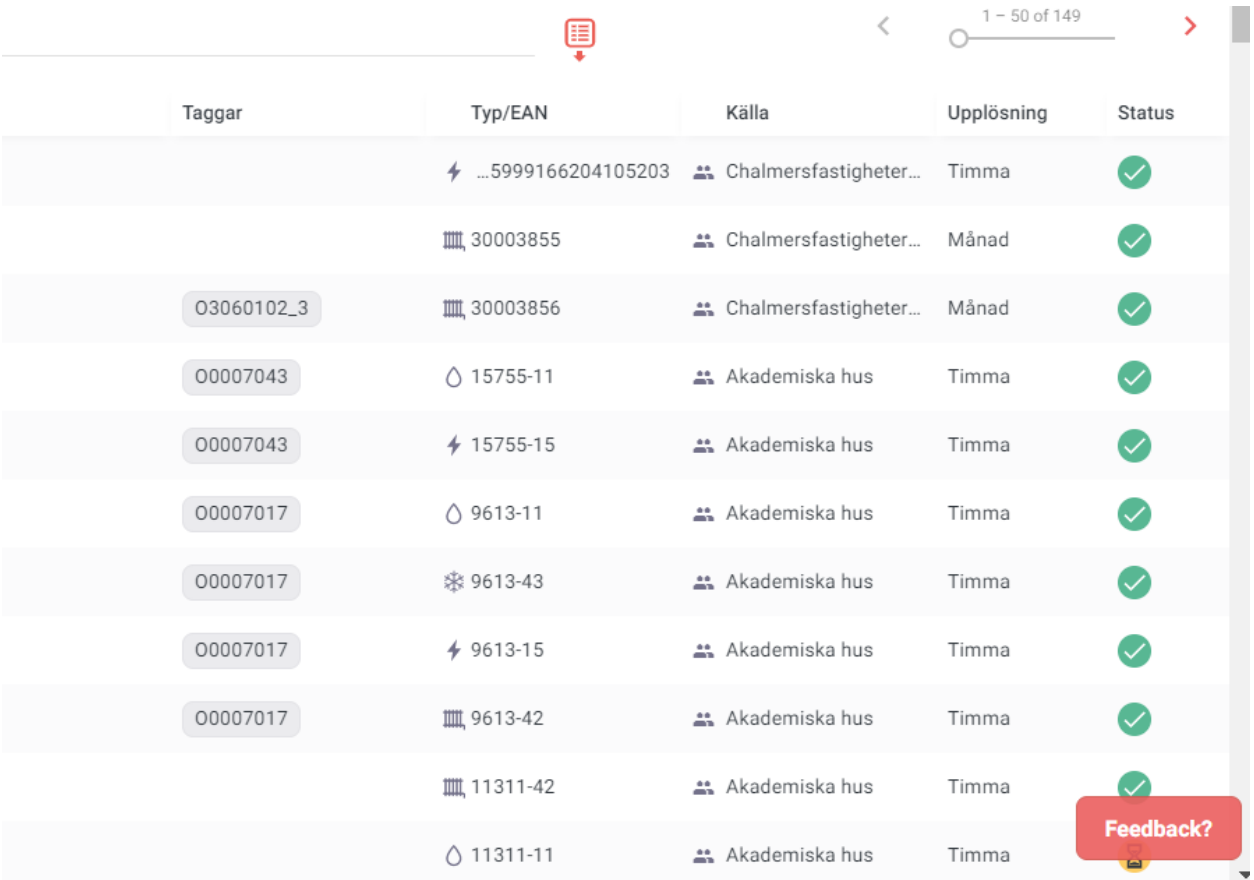
- Metry provides digital energy data and opportunity to share data between landlords, tenants, applications or even cities. Metry has connected to data from Akademiska hus and Chalmers Fastigheter within the project.
- Akademiska hus and Chalmers Fastigheter are managing a lot of data and some of this around 1 200 energy meters that has been integrated to the Energycloud platform and therefore available to be shared to tenants.

Chalmers, Högskolan i Skövde, Göteborgs Universitet example of academies (tenants) that are working on complying with the Climate Framework (Klimatramverket). With this Energycloud setup they have continuous access to the energy data that they need.

5.2.3 Preliminary results

From the Real estate owners in the project the result from sharing data to the University Tenants has been that quality issues in the data have moved higher up on the agenda. When data is being used by external parties such as tenants the demand on quality increase and that puts pressure on the data providers in this case the Real estate owners to improve quality of data. This has been both a positive and negative experience creating a new work-task to make sure quality issues are handled.

Data has been collected for all real estate owners and shared to every tenants. This data has then been integrated to the Business Intelligence system created in Microsoft Power BI by the third-party BI-consultancy company called Business vision. Figure 33 shows a print screen from the EnergyCloud platform showing data being shared from different actors to one of the tenants within the project.



1 – 50 of 149

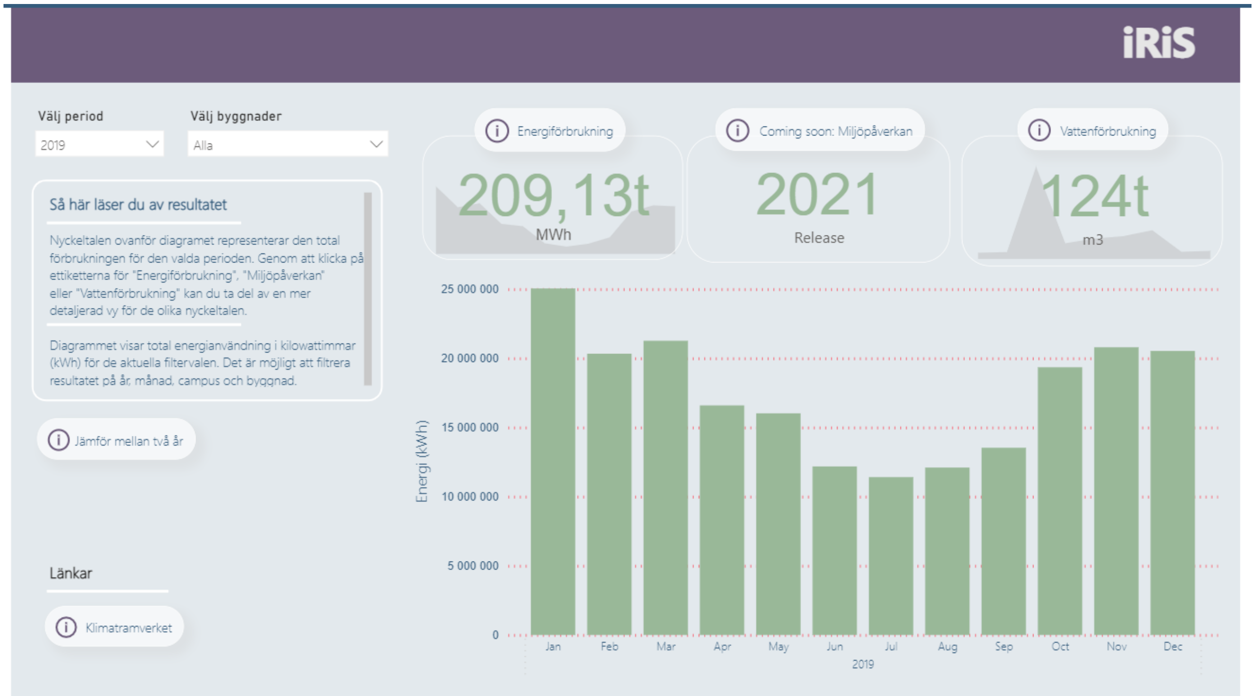
Taggar	Typ/EAN	Källa	Upplösning	Status
	...5999166204105203	Chalmersfastigheter...	Timma	✓
	30003855	Chalmersfastigheter...	Månad	✓
03060102_3	30003856	Chalmersfastigheter...	Månad	✓
00007043	15755-11	Akademiska hus	Timma	✓
00007043	15755-15	Akademiska hus	Timma	✓
00007017	9613-11	Akademiska hus	Timma	✓
00007017	9613-43	Akademiska hus	Timma	✓
00007017	9613-15	Akademiska hus	Timma	✓
00007017	9613-42	Akademiska hus	Timma	✓
	11311-42	Akademiska hus	Timma	✓
	11311-11	Akademiska hus	Timma	

Feedback?

Figure 33. Print screen from the EnergyCloud platform showing data being shared

Data has been shared using standard Metry API. There has been no need within the project change the integration-layer between the actors. Instead, we are using the standard Metry API when integrating data between Metry and the BI application. The actors within the project have not seen any positive effects by changing that to another format.

Within the project a BI-tool in Power BI has been developed to demonstrate how data easily can be integrated from the Energycloud into different services (Figure 34). The BI-tool has been developed in close collaboration with the University tenants and Real estate owners in the project.


iRiS
Välj period
2019
Välj byggnader
Alla
Så här läser du av resultatet
Nyckeltalen ovanför diagramet representerar den total förbrukningen för den valda perioden. Genom att klicka på ettiketterna för "Energiförbrukning", "Miljöpåverkan" eller "Vattenförbrukning" kan du ta del av en mer detaljerad vy för de olika nyckeltalen.
Diagrammet visar total energianvändning i kilowattimmar (kWh) för de aktuella filtervalen. Det är möjligt att filtrera resultatet på år, månad, campus och byggnad.
Jämför mellan två år
Länkar
Klimatramverket
Energiförbrukning
209,13t
MWh
Coming soon: Miljöpåverkan
2021
Release
Vattenförbrukning
124t
m3
Energi (kWh)
25 000 000
20 000 000
15 000 000
10 000 000
5 000 000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2019


iRiS
Välj period
2019
Välj byggnader
Alla
209,13t
Total energi (MWh)
Jämför mellan två år
Länkar
Klimatramverket
Fördelning
El
Kyla
Värme
El
Electricity (kWh)
10 000t
5 000t
0t
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2019
Värme
Heat (kWh)
10 000t
5 000t
0t
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2019
Kyla
Cooling (kWh)
1 000t
500t
0t
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2019

Figure 34. BI-tool for demonstrating how data easily can be integrated from the Energycloud into different services.

5.2.4 Key results

Fully scalable and integrated cloud for Energy data where any user can collect and integrate data into third party services.

5.2.5 Key recommendations

When applying a cloud service with data make sure that energy users can integrate and develop applications individually. The need for reports and visualization of data can change between different actors, regions, and types of buildings. Therefore, flexibility when choosing integrations and applications is very important. This has shown in the local Energy Cloud built within the project and considering all the different stakeholders there would be in applying this into a city then flexibility and ability to choose will be of high importance.

5.2.6 Key learning

Quality of data is usually not a topic that is highest on the agenda when starting to collect and present data. It is very common that quality of data is neglected in the beginning of these projects. However, quality of data has shown to be the biggest bottleneck in the EnergyCloud setup within the project. The local Landlords have their own systems and their own way of quality assuring, structuring, and naming the data created in the buildings. To unify this and allow tenants within the ecosystem to create their own quality assurance and structure has been the biggest challenge.

Table 19. Data Structure example

Data-set	Description
Address	Meta information. Example: Kungsgatan 2.
Name	Meta information. Example: Bruttomätning villa.
Type	What type of consumption the meter represents. Example: electricity.
Metrics	Which metrics the meter is recording data in. Example: energy
Representation	Does this meter record energy consumption or production. Example: production.
Generation Type	Integer that represents the current meters level in a tree structure, gen 0 (root meter) is held by the owner of the meter, gen 1 is the subscribed meter held by company or person that's energy usage is recorded by the meter, gen 2 is a shared meter which has been shared with a 3rd party.

5.2.7 KPI measurement

KPI’s for the Energy Cloud are shown in Table 20.

Table 20. Summary-list of KPIs and related parameters for Measure 4.2 Energy Cloud

Parameter(s)	2020	2021
Number of services based on open data	1	1
Number of data sets using DCAT standards	0	0
Total number of datasets	6	6

KPI	2020	2021	Target
Open data-based solutions	1	1	Number of applications using the REC compliant datasets in the Energy Cloud demonstrator are more than 3.
Quality of open Data	0%	0%	100% of DataSets in Energy Cloud demonstrator are REC compliant.

5.2.8 Business models and exploitation

Energy-data in buildings are stuck in vertical solutions. Sharing data and integrating to third party systems is usually connected to unstructured processes and manual work. This also means that the potential value-creation that can be made from data is not utilized.

In the EnergyCloud platform all energy-related data from all vertical data sources can be collected, qualified, and structured in a uniform way. This means that everything can be stored in the same platform and same format, allowing sharing, and integrating data in a uniform way to third parties.

The platform scales in a way that makes it useful for one building but also for an entire city (see picture below). Within this project there are discussions together with Gothenburg city in relation to the CIP they are implementing around digital data for the city. The city has published the first datasets with sensor data and there is an opportunity to use the results from EnergyCloud within the project to implement a cloud of Energy also for Gothenburg city. Technically this is already ready to be launched however there are organisational decisions that has to be made within the city.

Also, other cities in Europe are investigating how to utilize data in a better way. Creating open and reliable clouds of data will be necessary for any city that wants to increase digitalization. What has been showed in the Energycloud project within IRIS can be scales up to an entire city where data flows seamless between different stakeholders. This development is happening with energy data but also with any other data that is created within a city.

This creates many business opportunities for the results of Energycloud. Within the project sharing data from Real estate owners to tenants has been the use case. The USP with the results in this project is that tenants can get data shared from many property owners to the same Energycloud platform. A tenant usually rents offices or other facilities from more than one landlord. With the Energy Cloud energy data can be aggregated regardless of landlord.

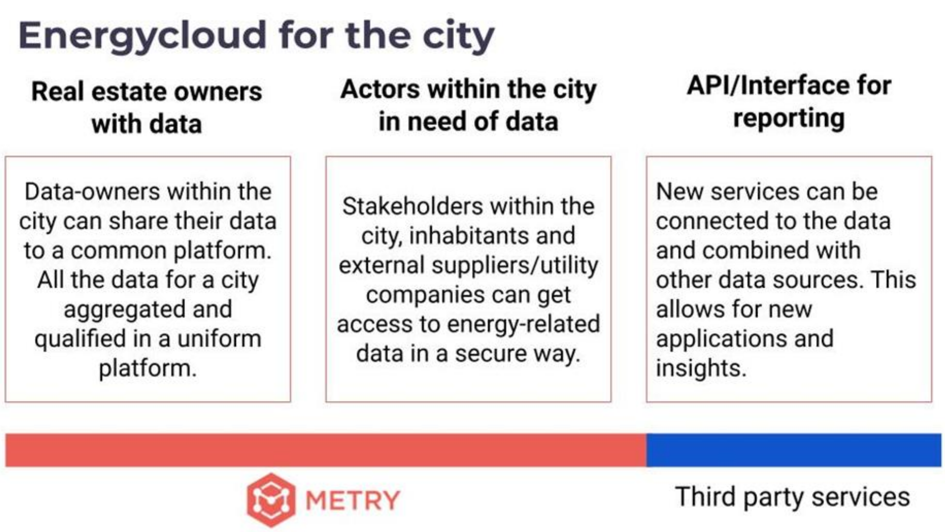


Figure 35. Business models for Energy Cloud

The business model that can be used based on this is a SaaS per meter cost where real estate owners and tenants are charged for using the SaaS platform.

Other value proposition that might be basis for revenue streams is that the user wants an overview of what actors that can access this data, both internally and external actors. The user also wants to administrate their metering infrastructure regardless of what meters are installed in the building. All this can be done through the EnergyCloud platform.

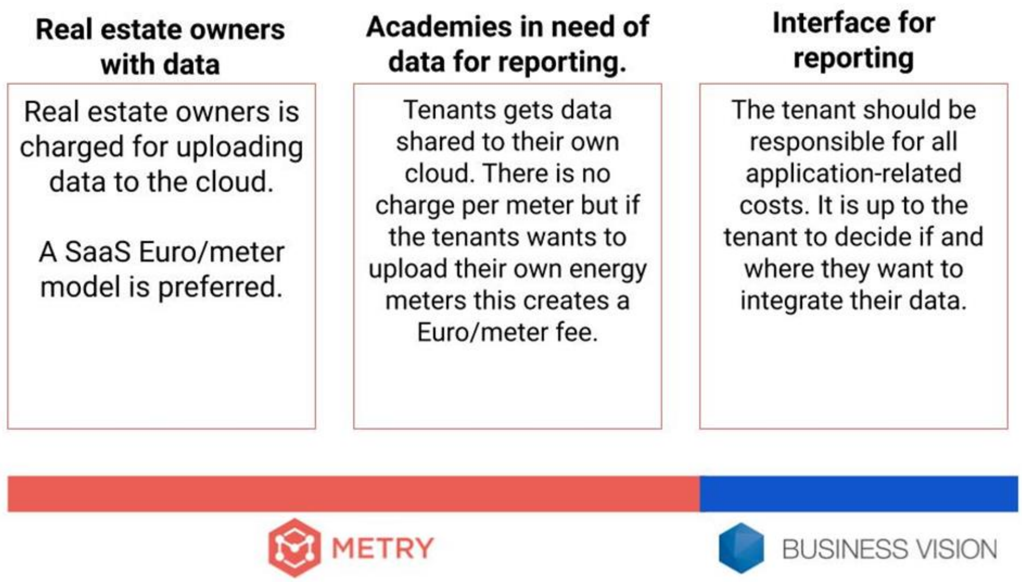


Figure 36. Business Models for Energy Cloud (2)

The business model that has been used within the project is that Real estate owners are charged by the EnergyCloud provider for uploading and allowing sharing of data to tenants. When tenants want to integrate data to third party services the tenant is responsible for the cost of the third party service.

5.3 Gothenburg CIP implementation

Gothenburg aspires to become a Smart City, where data from different domains can be combined to create a more vivid picture of a city. This will create new benefits for citizens, as it is the prerequisite for data-driven innovation/AI. Data sharing is central. To achieve data sharing for a Smart City, some key components have been identified: a City Information Model (CIM), which is the data model of the City data and a City Information/Innovation Platform(CIP) which is the platform used to share the data.

The earlier work done by different organisations within the City on CIM and CIP has led to a centralised project being initiated to establish a common service for CIP for all of the City. The project to establish the CIP as a service was started in the being of 2021 and is expected to have the first part of the service CIP in place during 2022. Work on CIP is expected to continue in different phases until 2025.

The CIM and the CIP of Gothenburg should not only handle static data in the form of 3D models of buildings, roads, schools, bridges, etc., but they should also be able to deal with real-time information from sensors used to measure temperature, traffic, soil moisture, bathing temperature, indoor climate, air quality, etc. Within the different areas of responsibility, the City of Gothenburg wants to create a living digital representation of the city. Therefore, a lot of data or just high-quality data within a sector is not enough. The data also needs to be in a format that makes it possible for the different systems to "talk" to each other and be scalable.

To better understand the challenges with sensor data, the City has been doing tests with technical connectivity platforms, particularly LoRaWan and 5G, to collect sensor data. For Gothenburg, the CIP will be fed with data from multiple data sources, where the first will be our IoT platform. CIP will make data available to more consumers than the original sensor/IoT solution. In other words, Gothenburg will create interoperability through CIP, maximise the value of our data by making it available to multiple consumers, make it possible to combine data with 3D models and create the prerequisites for data-driven innovation with AI, BI, etc. with standardised data models where data is interconnected. This is also an important part of the City of Gothenburg's Open Data initiative.

To meet this challenge, Gothenburg is working in both a top-down and bottom-up approach. The top-down approach is to define the requirements for CIP as a service, which will be built up of microservices, and specify how the microservices will be deployed supported and paid for. The bottom-up approach looks at different technologies to see which ones are the most capable and available for the city. In practice, this means the city needs to test different technologies to understand better how these technologies can be used to deliver the desired service described in the requirements in the top-down approach.

The first microservices to be implemented are soil moisture and bathing water temperature services. These have come a long way and will be published during 2021.

The latest developments in Gothenburg CIP and the new microservices (use-cases) are presented in detail in deliverable D4.7.

6 Preliminary Results of Transition Track 5

6.1 Overview

Within TT#5 we will present the preliminary results of the following demonstrators in IRIS Gothenburg:

a. The City of Gothenburg works with different types of civil society dialogues in various operations and processes. Minecraft, is a digital tool for reaching the younger citizens and is being demonstrated for use of dialogue with younger citizens regarding the development of a detailed plan and more. The Inclusive Life Challenge, is a concept we have developed for creating an arena were the city and its citizens can collaborate around aspects that make citizens more included in the development of the city. Within urban development, a public tool/platform has been developed in 2012; Min Stad (“My City”) (minstad.goteborg.se). It was developed for citizens where they have the opportunity to read others’ or create their own contributions and suggestions for urban development and there is a need to develop it further for stronger value regarding citizen engagement. ME-model, is a framework created to integrate the experience and learning from the three demonstrators: Minecraft, Inclusive City Life Challenge and Min Stad.
b. The ERO application have developed and demonstrated in the third generation house of HSB Living Lab, for nudging tenants to be aware of their energy use, and finally we will present the VR/AR BIM application within the office space of ”A Working Lab” where everyone can look into the office building in 3D as well through a developed application.

6.2 Minecraft, Inclusive Life Challenge and ME-Model

6.2.1 Implementation

Minecraft

- Children and young people at Bergsjöskolan have been invited to participate, 2 meetings during easter holiday week.

- The workshops has been carried out by Gothenburg city/City Planning Office and the Cultural Administration
- The working group for the workshops has consisted of the City Planning Office, the Cultural Administration, the NGO Bergsjön 2021 and the initiative Skolan in the center of the village/suburb.

The purpose of the application of the Minecraft tool in the zoning project is to investigate whether/how Minecraft can be used as a tool to engage children in a citizen dialogue to develop a draft detailed plan. In working with detailed plans that so clearly affect children's local environment and everyday life, it is of extra importance to strive to start from the children's own perspective. The hypothesis is that the application of Minecraft can facilitate dialogue with children, by the form of a computer game is both engaging and easily accessible to many children, and ultimately increase children's ability to influence the development of their local environment (in this detailed plan). The purpose of the two completed workshops is to put different dialogue tools in context, one of which is the digital tool Minecraft. The goal is to get an idea of how these tools can create an understanding of the project and its different perspectives, as well as generate issues that can be used as a basis for in-depth dialogue. The workshops have not primarily aimed to acquire knowledge for the planning process, but to test and evaluate Minecraft as a dialogue tool. Questions:

- Can Minecraft be used as a tool to gather knowledge for work on detailed plans?
- What information is possible to collect using this tool?
- Is this application of the tool suitable for increasing the interest and knowledge of schoolchildren in urban development issues?

Inclusive Life Challenge

The Inclusive Life Challenge is a concept we have developed for creating an arena were the city and its citizens can collaborate around aspects that make citizens more included in the development of the city. Inclusive Life Challenges can be carried out in various formats. In IRIS we implemented the Inclusive Life Challenges as a part of the Bachelor's degree level course *Leading in a Digital World* at Chalmers University of Technology in Gothenburg, Sweden. The course has dual purposes: 1) to teach students about strategic thinking and leadership in a global and digital world by teaching them how to use new technology to transform value creating activities both in organizations as well as in society. 2) to help a city (in this case the City of Gothenburg) to fulfill its vision towards a Smart City (regarding circularity and sustainability). The students are expected to develop a digital innovation and accompanying business model.

In total, 100 Chalmers students divided into 18 teams, worked on their ideas in their live case projects for the City of Gothenburg over a timespan of eight weeks. The course started in January with a kick-off lecture and during March to May, the Innovation pitch videos were displayed online for public voting and the Innovation pitch posters were planned to be displayed at an exhibition area in the city. Unfortunately, the pandemic restrictions gave obstacles for the physical exhibition, and it was presented online.

Each team had to select an innovation focus area and geographical location, i.e. one of the boroughs of Gothenburg. The teams worked on ideas about reducing food waste, improved mobility and air quality, water use management, a student accommodation platform, waste sorting and connected urban farming. To develop a solution to their challenge, the teams had to collect market information, use open data provided by the City of Gothenburg and available from other sources and test their own as well as others' assumptions. Towards the end of the eight weeks the teams pitched their digital innovation solution to the City of Gothenburg's jury, the citizens of Gothenburg, the faculty, and their fellow students and tried to convince them that it is a great innovation for the City of Gothenburg and its citizens.

Min Stad – understanding users of digital platforms for city development

We invited a pair of students at Chalmers University of Technology to conduct a study as a part of their Master's degree on what motivates citizens to use the digital platform Min Stad and how to develop *Min Stad* as a dialogue tool. The 30 ECTS Master's thesis project was conducted August 2019 to January 2020. The Master's thesis (Report No. E2020:123) by Helldén and Zhao is attached in the Appendix.

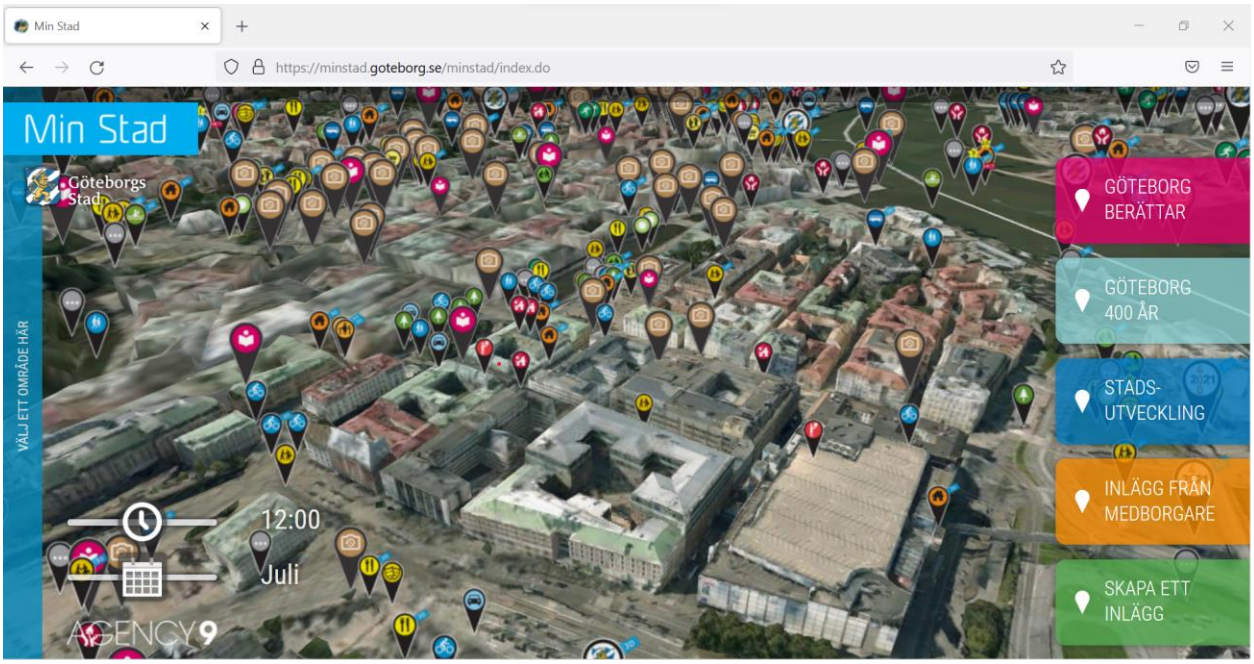


Figure 37. A screenshot of the application Min Stad

"Min Stad" (My City) was created as a website in 2012 by the city of Gothenburg and has later also been launched as a mobile application. The application serves multiple purposes for the city. It can be used as:

1) Idea inbox: citizens can suggest ideas on things that need to improve within the city and tag them with a specific subject on a specific location
2) Visual information sharing: the city can visually share information on various city development or infrastructure projects that are going on or are planned around the city
3) Story sharing: both users and the city can share stories or historical facts behind specific geographic locations within the city

The website and the app are 3D-maps over the city where users can explore all posts that other users or the city have posted throughout the city as well as post their own contributions. Min Stad has a total amount of more than 1400 posts from citizens. A post is often a short comment e.g. "this traffic light is broken" or "rebuild this city area to a large park". Figure 37 shows a screenshot from the application.

ME-model – citizen engagement model

The fourth demonstrator the citizenship engagement model (In Swedish Medborgarengagemang, hence ME-model (see Table 21) is a framework created to integrate the experience and learning from three demonstrators: Minecraft, Inclusive City Life Challenge, and Min Stad. The purpose of the model is to contribute to the city's further work on citizen engagement by means of digital platforms by highlighting what rights and obligations i.e. pointing to for example expectations citizens as well as the city have when launching digital platforms to engage citizens in city planning and development. The ME model can also be used to discuss what kind of organization and facilitation the various types of citizen engagement require. The ME-model has been developed through a series of workshops mainly with people working with tasks related to citizen engagement, democracy, city planning.

Table 21. ME-model for citizen engagement

Type of engagement	Citizens are informed	Citizens give feedback	Citizens have dialogue with each other or the city	Citizens co-create with each other or the city
Inclusive Life Challenge	Yes	Yes	Yes	Yes But could be improved
Min Stad	Yes	Yes	No	No
Minecraft	Yes	Yes	Yes	Yes But could be improved
Citizen engagement	Low ———	———	———	High
City engagement	Give information	Give response	Give information and response Show interest	Give information and response Show interest and use Provide tools

The ME-model shows that the moderators used implies that the city was interacting with the citizens in different ways: informing them, receiving feedback from them, having a dialogue with them, or even co-creating with them. What we learnt from the demonstrators was that the Inclusive Life Challenge and Minecraft has even more potential for engaging the citizens in co-creation but the prerequisites for this needs to be improved and the city needs to improve their organizational capability to engage in co-creation with the citizens. The model also shows that the different moderators require varying levels of engagement from the citizens as well as changing types of engagement by the city, which implies that it should be clear in "the contract" what expectation the city and citizens can have on each other.

We have also thought of the demonstrators in the light of city governance issues. Hilgers and Ihl (2010) have developed a framework for citizen engaged governance outlining three main types of citizens engagement – citizen ideation and innovation, collaborative administration, and collaborative democracy - that can be part of the city's advancement towards a more open governance model were citizens play a crucial role. We mapped our three demonstrators in relation to these three types and found that they can be considered as examples of how to design citizen engagement in accordance with the Hilgers and Ihl

(2010)[2] framework. As illustrated in Figure 38, the Inclusive Life Challenge conducted with students at Chalmers University of Technology demonstrates how citizens can be engaged in ideation and innovation, the Min Stad Master's thesis study results demonstrate that a digital platform has the potential to become a tool for collaborative administration, and the Minecraft event at the primary school demonstrate that a digital game and play can engage citizens and enable collaborative democracy.

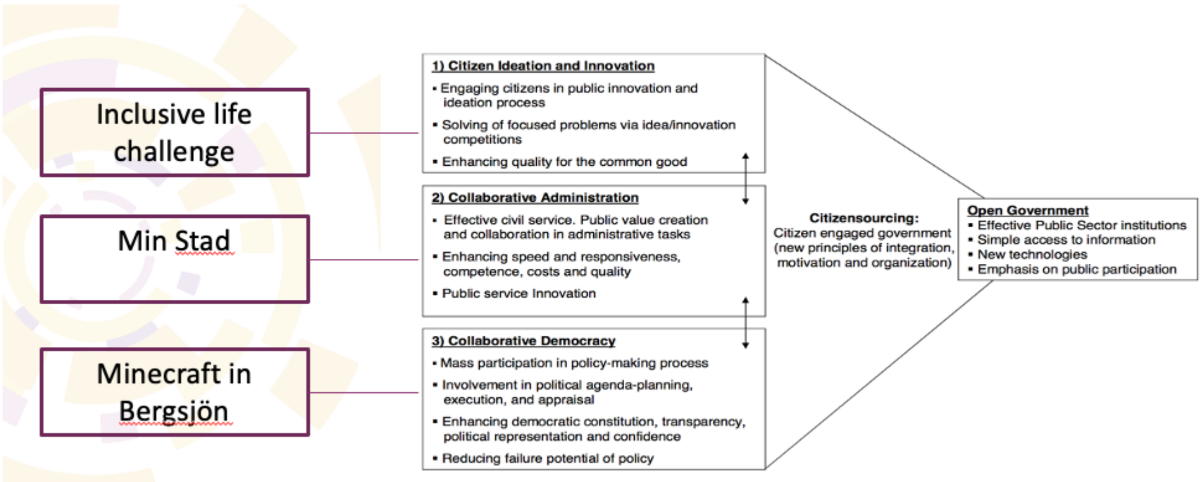


Figure 38. Citizen engagement for participatory city modelling

6.2.2 Preliminary results

Minecraft

Minecraft has been valuable above all in understanding the scope and volume of the changes proposed, which may otherwise be too abstract to have thoughts and opinions about. It should be taken into account that the children who participated have been invited to use Minecraft. We should therefore read the conclusions on the basis that the initial workshops have been carried out with participants who have an interest in and prior knowledge of the tool we are going to test and evaluate.

We have used several of the questions from the working group, regarding children's movement patterns, relationships with the district, etc., to have something to apply "Can we use Minecraft to extract information from children and young people in urban planning projects" on. Because we had so few participants, we can't draw such big conclusions, but the children and young people who were there have all expressed that it has been fun to play Minecraft and that it has helped them understand what the proposal for the area means.

Using the game Minecraft as a tool requires a certain structure and guidance. On the one hand, we use the play signal in the tool to engage children and young people, but on the other hand, we need to drive

[2] Hilgers, D., & Ihl, C. (2010). Citizensourcing: Applying the concept of open innovation to the public sector. *International Journal of Public Participation*, *4*(1).

the investigation through the game to extract information. There are elements in the game that can take the focus away from what we want to explore. The fact that there is suddenly night and monsters appear in the district we inventory is exciting for the player, but at the same time can be distracting for the mission.

- Can Minecraft be used as a tool to gather knowledge for work on detailed plans?

Minecraft has been used in this project to contribute to a better understanding of the planning area and the suggestions available for the development work.

The game itself has not gathered knowledge but has been used as a tool to give participating children as clear information and understanding of the subject and area as possible. Based on this, the children and young people who participate can formulate questions, thoughts and opinions that can then be used as knowledge in the work with detailed plans.

The game includes opportunities to visualize ideas and suggestions, but it has not been included in this feasibility study.

- What information is possible to collect using this tool?

The definition of a tool is that it facilitates the work. The question is not whether Minecraft can be used completely independently to gather information, but the premise is that it is used in a context - educational or rhetorical.

Minecraft can be used as one (or one of several) tools in dialogue methodology to help gather whatever information children and young people might have to contribute.

In this case, Minecraft has been used along with a couple of other tools for dialogue and all participants have expressed themselves positively to experience the environments that under foundation the issues, in the game.

The assessment is that it may feel less abstract to experience the volumes of suggestions in the living gaming environment, compared to seeing renderings, floor plans or sketches. The play aspect of exploring a topic within a digital game can also make it easier to get away from what we call the school effect - that is, that children perceive that there is the right answer to questions asked by adults, and that in the classroom they would like to answer what they think the questioner wants to hear.

- Is this application of the tool suitable for increasing the interest and knowledge of schoolchildren in urban development issues?

Schoolchildren participating in dialogue projects are generally composed in groups based on age and where they live. A class therefore consists of individuals who can be at very different levels of prior knowledge, have widely different interests and prefer different techniques both to absorb knowledge and create information.

If the goal of a project is to formulate as nuanced and comprehensive a child perspective as possible, in order to use it on good grounds in the work on, for example, detailed plans, then a suitable application of the tool Minecraft is to include it in a dialogue methodology that is designed based on the scope, conditions, issues and need for results of the specific project.

The two initial workshops have aimed to test and evaluate Minecraft as a dialogue tool, together with students from Bergsjöskolan, and to start formulating questions among participating children and young people. The goal is to understand how the dialogue tools can be used and the issues we find will serve as a strong basis for in-depth dialogue in the continued work with BKA in the planning process.

The three meetings that were carried out have been perceived as positive, and participating children and young people have enthusiastically and generously engaged in the challenges presented to them.

The experience of Minecraft as a tool is that it can be rewarding and valuable in dialogue projects with children. It is an open and adaptable tool, which can facilitate certain aspects of an investigative and creative process.

We may include questions regarding extended uses (as in this preliminary study we have tested a limited area), how the participants' existing interest in the game and prior knowledge affects their use, and what accessibility looks like as the game requires access to computer, tablet or smart phone as well as software.

Inclusive Life Challenge

The 100 students taking part in the course and working with their live case projects in collaboration with the City of Gothenburg were very engaged as they were working with issues concerning their own surroundings, which had a positive impact on their learning. The citizens who engaged in voting for the idea they liked mostly appreciated the opportunity to get involved in the process by showing their preference.

The winner of the Inclusive Life Challenge Matvinn (Figure 39) impressed both the general public when they voted as well as the jury. Matvinn is an app to enable the saving of food waste from school kitchens by allowing students' parents to bring food boxes home with leftovers. Thus, Matvinn solves two issues simultaneously, i.e. the climate impact of food waste can be reduced while the everyday lives of families are made easier. The app was not fully developed during the course, but the team has been in contact with a school in Gothenburg, Sweden, that has shown interest in the project. The winning concept were also addressed by at least two housing companies within the city of Gothenburg that were interested of a collaboration. Unfortunately, the students were split geographically and did not have the possibilities to develop the concept together with the interested parties.

Figure 39. The poster for the winning idea Matvinn

Min Stad – understanding users of digital platforms for city development

The master's thesis was sent to the three persons from the city that took part in the study and were interviewed. The recommendations put forward in the thesis are:

1) the city's purpose with the platform Min Stad needs to expand beyond that of an error reporting/complaints channel or graffiti board for citizens since it has potential to motivate citizens to be engaged and responsible co-creators of the city

2) the city's purpose with the platform Min Stad needs to be clarified for the citizens to mitigate expectations, either in its current form or if developed into a platform for co-creation with the city

3) developing the platform to reach critical mass is required, and that one approach to growing could be through a beachhead strategy commonly used by other successful digital platforms.

In the master's thesis project, the activity on the Min Stad platform was analysed and the results show that the number of posts has steadily been declining from around 350 posts in 2012 to less than 50 posts in 2020. Interviews with users of the platform were conducted. The analysis of the interviews with users showed that people viewed the platform as a tool for communication, mostly with the city but also with other citizens. The users expected some sort of feedback on their posts and felt like their efforts were useless when they did not receive any reaction. With feedback they meant a comment from the city or a fellow citizen. The users perceived the platform to be dead and trying to achieve anything on it felt pointless. They said that the value of feedback is enough to motivate their efforts on the platform even if their suggestions are not implemented. The analysis of the interviews indicates that the main reason users are not returning to the platform is caused by the lack of feedback and the low level of activity on the platform.

To contribute to the understanding of citizens' motivation to participate in the development of their city a concept called *citizensourcing two-factor motivation,* building on previous research on dissatisfiers and motivators, is presented (see Table 22).

Table 22. Citizensourcing two-factor motivation (Helldén and Zhao, 2020)

Citizenship Identity	City Life Conditions
Achievement	Safety
Recognition (by fellow citizens and politicians)	Mobility
The work itself	Infrastructure
Growth	Public goods
Responsibility	City tax rate and fees
	City rules and regulations

City Life Conditions are dissatisfiers and refer to the conditions of citizens' city life, i.e. their life outside of work and home. Citizens expect these conditions to meet their expectations as a citizen in the city and will not become more motivated or happy with their life even if these factors are much better than expected. However, if one of these City Life Conditions is not working as expected, they can cause a citizen to become very dissatisfied with their life as a citizen in the city. One example is that a citizen can be expected to be dissatisfied if public transportation (mobility) is not working according to expectations.

Citizenship Identity refers to factors that motivates citizens in a city life setting, outside of home and work. Citizenship identity builds on the idea that an individual knows that he or she belongs to a social group that holds a common social identification and strives to become a good member of that community to feel good about him/herself and receive status within the group of other citizens. This citizenship identity motivates them to contribute to the community i.e. the city. For instance, the motivator "recognition" refers to being recognized by fellow citizens or politicians.

6.2.3 Conclusions, lessons learned and next steps

Challenges of citizen engagement:

- The challenges of the city include different understanding of what citizens are and this is rarely discussed, some who see themselves as owners of the relationship with citizens (young children and young people), the implementation of digital solutions for dialogue with citizens difficult as these are not "approved" to have dialogue with citizens

- Understanding what motivates citizens to be active in the city's governance and development is too low. Here we can take up reflections from the master's thesis.

Lessons:

- Cooperation with the school system create win-win situation
- Create arena for conversation and cooperation on citizen engagement issues "Citizens care - they're committed but maybe not on all issues all the time we have to help them direct their commitment to the right thing at the right time (here's some from the master's thesis).

Next steps

- One more activity will be conducted within the demonstration Minecraft. An activity was planned within the City Triennale. Due to challenges related to the pandemic, the activity has now changed to another project.

A collaboration within Citizen Engagement through Minecraft is planned with the school Lärjeskolan in Hjällbo. The Vice-Chancellor has given positive information that they would like to participate in this. The activity will be performed within Child Consequence Analysis (BKA) within the city development program for Hjällbo (Figure 40), which aims to densify and quality-enhancing measures of the public spaces. The activity will be carried out through 2-3 workshops at Lärjeskolan. An architecture educator / pedagogue leads the work. The reason to conduct one more activity within the demonstrator is to test the tool with a large group of children and within another scale of planning project.

- Time of implementation: Januari-Februari, 2022.
- Implementation resources: Project Manager: Anna Reuter Metelius (City Planning Office), Deputy Project Manager: Martin Trpkovski (City Planning Office), Minecraft specialist: Robin Nilsson (City Planning Office), Planner: Jesper Adolfsson (subcontracting), Architecture Pedagogue through subcontracting.

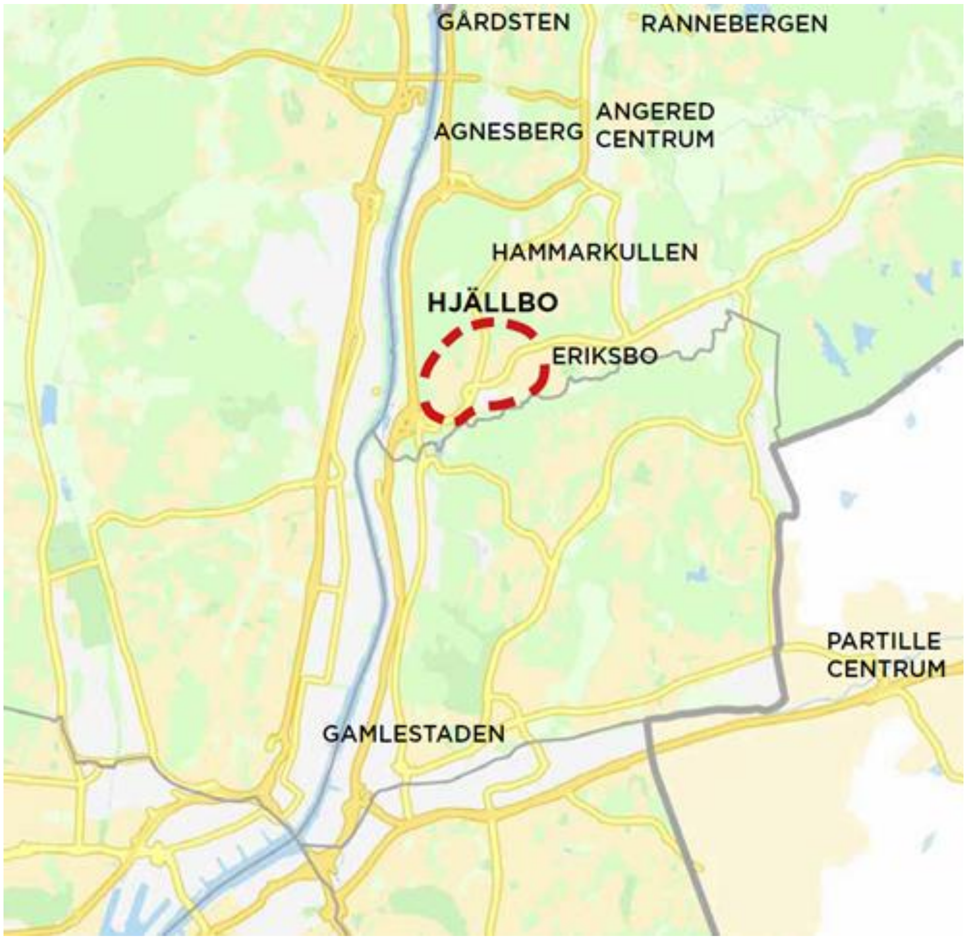


Figure 40. The area for a planning program in Hjällbo

Further work will be carried out on the Min stad/My City platform. The platform has just undergone a development and its new opportunities will be discussed during a number of workshops.

6.3 Personal Energy Threshold (PET)/ERO application in HSB Living Lab

Key message and learnings

- Close collaboration between researchers and IT-professionals.
- The scope was limited which meant that all key competences could be kept within the team.
- Re-use of infrastructure components. The project had the benefit of building the solution on top of a solid IT-infrastructure provided by Chalmers focusing work on the specific tasks of the project rather than building infrastructure components.

6.3.1 Overview

The demonstration of PET - Personal Energy Threshold was demonstrated in HSB Living Lab in the Lighthouse City district Campus Johanneberg. Within the PET project an application was developed for monitoring energy usage and then giving feedback to users regarding their personal energy consumption and it was designed for a smart home system in mind that could balance the energy demand and supply. The app had a function called Personal Energy Threshold (PET), a momentary power level showing when there is plenty and short of energy in relation to the household's energy consumption. Sara Renström, PhD, studied the behaviour of users throughout the demonstration aiming at how energy functions in a smart home can be monitored, accessed, and controlled. Users of the app was people living in HSB Living Lab. Target group/groups could be any citizen with total or some possibility to control their energy usage (Figure 41). The expected impact was to develop a deeper understanding of the tenants' energy consumption at individual level, and let each individual choose what type of energy source to be used and when. Through the developed application ERO the aim was to nudge individuals to choose "green" energy such as energy from the installed PVs (façade and roof). The cost of the participants energy use was included in the rent.

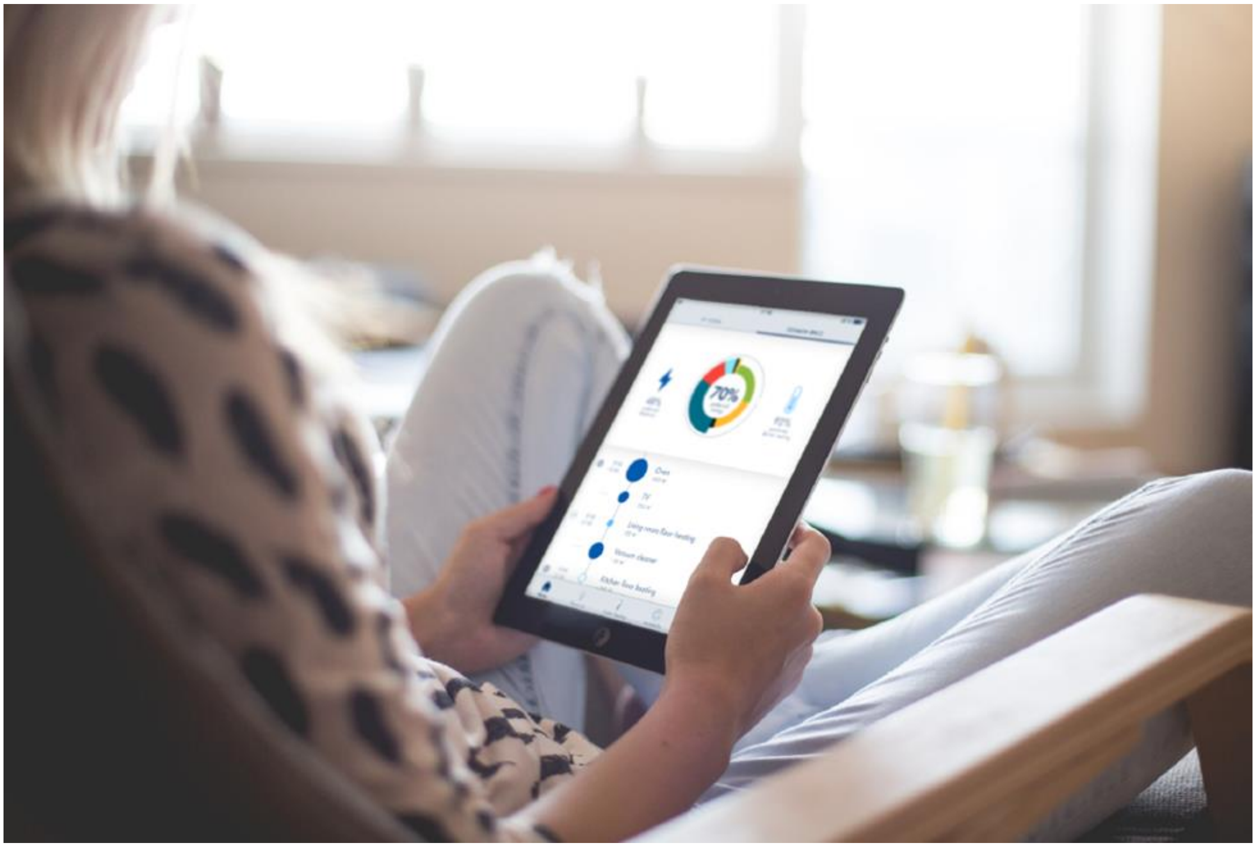


Figure 41. Tablets were used when interacting with the ERO application

The demonstration took place in 2017 and 2018 and unfortunately did not go ahead for development. Among other things, there was a lack of funds to move forward. The technical and research implementation results, have been reported in D.7.7

6.3.2 Lessons Learned and Next Steps

The overall aim was to explore what roles households can play in the smart energy networks of the future and what digital solutions are required to make this possible. In the current project, a demonstration was carried out with users and residents in HSB Living Lab.

In the future energy system, it can be of great benefit with conscious and committed end users of energy, which can help reduce power peaks and environmental impact through behavioural choices.

In the future, it will be possible to connect Ero with other projects in smart energy systems.

- It was unfortunately not possible to connect the district heating and the solar energy storage system to the PET application. The focus then, was electricity usage.
- Seven participants took part in the study and none of the participants used ERO extensively. The particpants own experiences was that they did not use much energy and could not then optimise much energy.
- The results gave conclusions that it was possible to create a smart home system. The function the application had, to serve as an energy status lens, was anyhow appreciated by the participants.

- **ERO/PET app**

- Technically a replication could be arranged as the code is available in GIT and will in part be re-used in coming projects.
- The application was appreciated by the users, but many of them questioned the extent to which their demand shifting could contribute.
- Some positive lessons learnt was the close collaboration between researchers and IT-professionals, and the re-use of infrastructure components. The project had the benefit of building the solution on top of a solid IT-infrastructure provided by Chalmers focusing work on the specific tasks of the project rather than building infrastructure components.
- No next steps are being taken for this demonstration.

6.4 AR/VR BIM Visualisation Demonstrator

6.4.1 Overview

A modern building is a very complex entity, consisting of a multitude of components, sub-systems and materials. In order to manage and keep track of this complexity, the so-called Building Information Modelling) BIM method, has emerged as a standard mode of working for making digital representations of buildings.

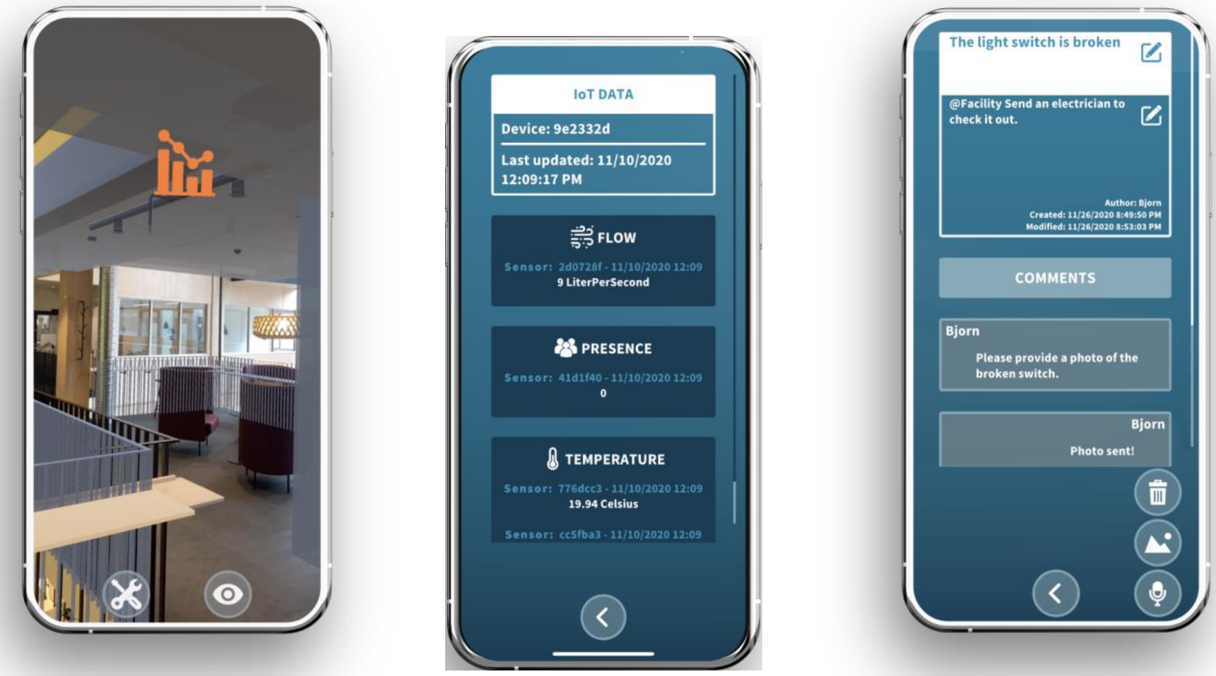


Figure 42. Screenshot from smartphone, of the AR environment in AWL (left), IoT data (middle), and the annotation feature (right)

A BIM model is a virtual model of reality. In the model, all information from a building's life cycle is collected and organized. The BIM model can contain information about both the physical and the logical composition of the objects and the building itself. The BIM model can be described as a virtual prototype. A BIM model consists of an object-based, digital representation of the constituent components.

Figure 43. The VR app is accessed through an Oculus Quest headset

Figure 44. Screenshot from VR environment in AWL building

The aim for the demonstrator was to create a way for anyone to view a building's BIM components, either by interacting directly with the building in an AR (Figure 42) environment, or remotely in a VR (Figure 44) application. This could provide interesting insights into the "inner workings" of the building as well as to act as a tool for those working with building management and maintenance.

As an added feature, the AR and VR apps are also able to visualise IoT data from the building's sensors. All in all, 500 sensor locations are installed in the building, providing information about properties such as temperature, occupancy, air quality and noise (Figure 42).

For property owners, the visualisation will provide easy access to BIM data. Currently, property owners rely on third parties such as consultants or design firms to handle and provide access to BIM data. With this system, BIM data will be readily available without having to employ expert resources, providing greater understanding of the building's working and performance. The system can also be used as a means of communication with the tenants.

Maintenance and technical staff may use the system as a tool to simplify identification, specification or malfunctions and problems as well as execution of repair and maintenance tasks, for instance by using the annotation feature (**Fout! Verwijzingsbron niet gevonden.**), where the user may interactively add new data to BIM objects in the form of annotations. Annotations may thus be used to create issues and, if desirable, integrated into an issue tracking system.

Also, tenants and visitors could benefit from the app for navigation and orientation, to get acquainted with the building and its innovative features. Table 23 shows KPI's for the demonstrator.

Table 23. KPI's for AR/VR visualisation demonstrator

KPI	Parameter(s)	Baseline	Preliminary results	Target (as described inDoW or declared)
Increased environmental awareness	The extent to which the project has used opportunities for increasing environmental awareness and educating about sustainabilityand the environment. (Likert scale)	N/A	Not yet available	Not defined
Ease of use for end users of the solution	The extent to which the solution is perceived as difficult to understand and use for potential end-users. End-users are conceptualised as those individuals who will be using/working with the solution. Some solutions or innovations are perceived as relatively difficult to understand and use while others are clear and easy to the adopters. It is presumed that a smart city solution that is easy to use and understand will be more likely adopted than a difficult solution (Likert scale)	N/A	Not yet available	Not defined

6.4.2 Lessons Learned and Next Steps

The AR and VR apps were launched in the autumn of 2019, but due to some initial improvement work, there was only a small amount of use in the first months. As the Covid-19 pandemic caused most people to relocate their work to their homes, there has been little use of the apps during 2020 and 2021. Thus, meaningful results are still lacking. Actions will be taken to promote the use of the AR app as tenants and visitors are beginning to return.

7 Preliminary Results at the Lighthouse City Level

7.1 Introduction

The City of Gothenburg has eight policy-guiding programs, a multitude of plans and several rules to work from to achieve an improved environment and improved climate work directly related to the global goals. It is however impossible for a municipality to achieve the goals by itself, and there is also a programme to support and drive innovations as a municipality needs to grow and achieve good results. Through "*Innovationsprogrammet"* (the Innovation Programme) the objective is to increase the City of Gothenburg's capacity for innovation within the City's organization, in collaboration with other sectors of society, and also to increase the City's ability to contribute to a strong innovation system in the Gothenburg region. During the IRIS consortium meeting in Nice 2019, one Gothenburg City 4representative participated to give a presentation to this effect.

The City of Gothenburg are connected as signatories to the Covenant of Mayors and has also signed the New Covenant of Mayors in May 2020 which extends to 2030. This contains a vision for 2050 for the connecting cities to work for climate adaptation that will lead to sustainable resilience and that carbon dioxide emissions will be reduced by 40% by 2030, through increased energy efficiency, and increased use of renewable energy sources. The accession provides an opportunity to compare oneself with other cities and to share knowledge with local and regional authorities within and outside the EU.

This section of the report aims at describing how IRIS activities, demonstrations and experiences have contributed to form activities and policy development on part of the public stakeholders in the Gothenburg region, mainly the City of Gothenburg.

7.2 Impact on the Lighthouse City Level

IRIS Impact on Gothenburg's Energy Plan

The starting points for the steering of the City of Gothenburg are laws and constitutions, the political will and the city's residents, users, and customers. To realize starting points, preconditions of various kinds are needed. City politicians have the opportunity through governing documents to describe how they want to realize the political will. One such governing document currently being drafted is Gothenburg's Energy Plan 2022-2030.

The purpose of the energy plan includes

- Promoting the implementation of measures that lead to the City of Gothenburg achieving the following goals in the City of Gothenburg's environmental and climate program 2021–2030:
    - Reduce energy use in homes and premises
    - Produce energy only from renewable sources
    - Reduce the climate impact of transport
    - Maintain and develop the city's work to have a safe and secure energy supply

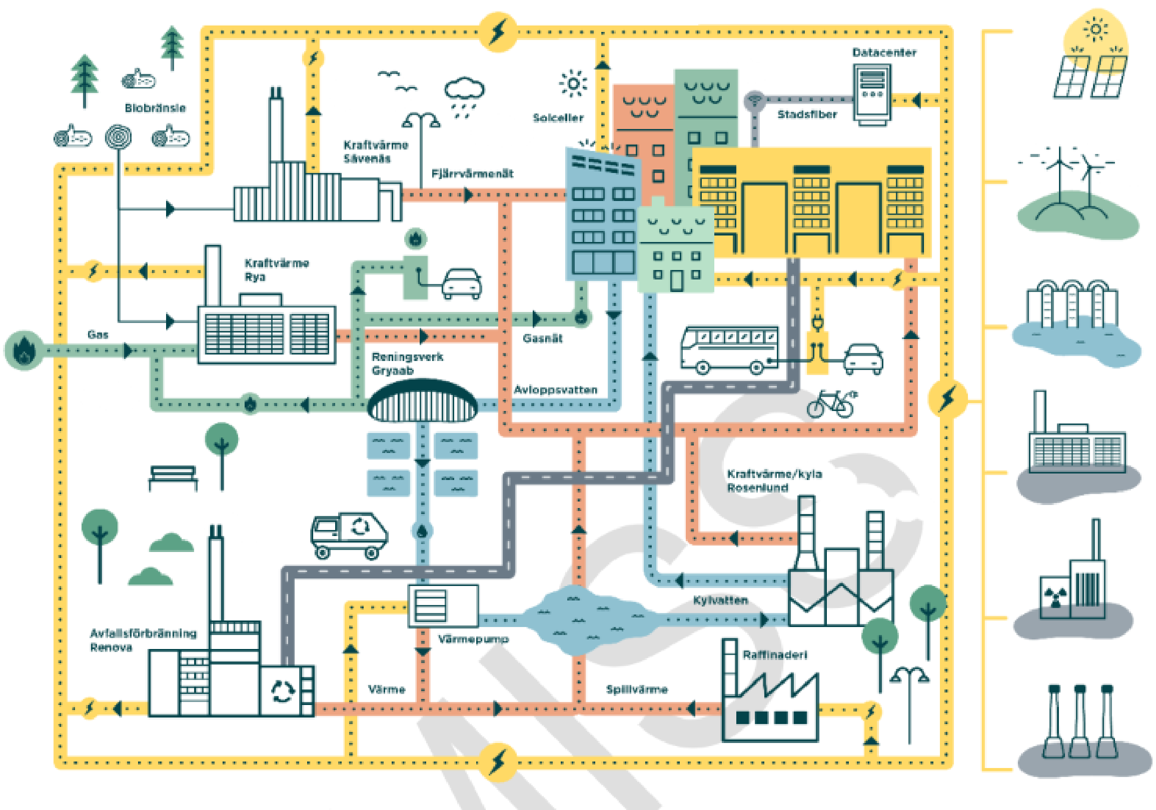


Figure 45. A schematic of Gothenburg's energy system (City of Gothenburg)

IRIS impacts in Gothenburg’s Energy Plan include the following.

Flexible and capacity-secure energy system

Today, the City of Gothenburg actively participates in innovation projects and should continue to prioritize research collaboration and participation in pilot projects concerning controlled use and storage of electricity, heating, and cooling in order to increase the robustness of an energy system (Figure 45) that faces more and greater challenges. The energy solutions (local power generation, storage, and management) piloted in Viva and A Working Lab in IRIS TT#1 have contributed greatly to the understanding and provided the groundwork for further developments. The City of Gothenburg has also profited from learning from LHC Utrecht’s V2G demonstrator.

Impact: Göteborg Energi AB will, together with Förvaltnings AB Framtiden, start pilot projects to develop and implement technologies for smart control of power use in the electricity grid, in combination with energy storage, to investigate the possibility of reducing electricity power peaks on a large scale. The lessons learned from the project will be disseminated to other property owners and management companies and committees within the City of Gothenburg.

Impact: "Göteborg Energi AB, together with Förvaltnings AB Framtiden, will start pilot projects to investigate the possibility of reducing heat output peaks in apartment buildings on a large scale through smart control and heat storage. The lessons learned from the project will be disseminated to other property owners and management companies and committees within the City of Gothenburg."

Impact: "Göteborg Energi AB shall, together with other relevant actors, actively work for the management of electricity power use and a stabilization of the electricity power demand in Gothenburg. This by taking advantage of the potential for demand flexibility through, for example, Vehicle-to-Everything (V2X) technology, smart power control of electric car chargers, central and local electricity storage and power control of heat pumps for residential customers", as observed in the lessons from Utrecht

Renewable and recycled heat

"That premises and housing in Gothenburg are heated in a sustainable way is a prerequisite for the city to achieve set climate goals. As part of the work to reduce Gothenburg's climate impact, district heating in the municipality will consist of only renewable and recycled energy by 2025. This means that Göteborg Energi AB needs to decommission existing fossil fuel-powered CHP plants and replace them with renewable equivalents. This work has already begun. Based on the fossil emissions from district heating production in 2017–2019, the total emissions can be reduced by 70,000–120,000 tonnes per year through this conversion. Continuous cooperation is already underway with existing heat suppliers in order to optimize deliveries and increase the proportion of heat recovered in the district heating mix. An exchange also takes place with adjacent municipalities that have their own district heating systems."

The demonstrators in Viva have made extensive use of heat pumps, low temperature district heating, heat recovery and storage. Göteborg Energi, as an IRIS partner, have been able to profit from the results and learnings from these demonstrators.

Impact: "Göteborg Energi AB will continue to follow developments, investigate and work for, where appropriate, combination solutions where district heating and heat pump are used together for heating."

Impact: "Göteborg Energi AB will continue to develop district heating to be as long-term sustainable as possible by investigating opportunities to favour recycled heat with renewable and sustainable origins."

Energy efficient and fossil-free travel, transport, and work machines

"Gothenburg's population is assumed to grow by just over 60,000 inhabitants between 2020 and 2030 (City Management Office, City of Gothenburg, 2020). If the additional population travels with the same distribution of vehicles as today, energy use within the transport sector will grow in an unsustainable way. If fossil-free fuels and electricity capacity shall be sufficient, travel and transport need to be reduced and to become more efficient. The goal in the environmental and climate program is that road traffic work will be 25 percent lower in 2030 compared with 2020. To reach that goal, traveling on foot, by bicycle and public transport needs to be stimulated and prioritized in relation to car traffic. The role of urban planning is important to achieve this, as factors such as population density and infrastructure affect travel patterns. Too low population density (for example, large single-family housing areas) tend to create car dependency. Densification in combination with improved infrastructure for sustainable modes of transport can contribute to reducing road traffic work and the transport sector's emissions.

Electrification of the transport system also means, in addition to sharply reduced emissions, a more efficient energy use compared to internal combustion engines."

In Viva, IRIS has piloted a car-free life-style with zero private parking space allotted, where residents instead have had access to a range of transportation services such as electric vehicles, electric bicycles and public transport. The City has followed the outcome of this experiment and has stated that it is favourable towards flexible parking norms as a means to reduce private car use.

Impact: "Förvaltnings AB Framtiden will offer mobility alternatives, such as electric cars or cargo bike pools, as a complement to public transport for all residents. The purpose is to contribute to reduced car travel and to increase the probability that private individuals choose sustainable alternatives to conventional ownership of fossil-powered vehicles Measure: Förvaltnings AB Framtiden, byggnadsnämnden, fastighetsnämnden and Göteborgs Stads Parkering AB, shall prioritize parking spaces dedicated to carpools over private parking spaces."

IRIS Impact in other areas

Open data

In the service plan for Gothenburg Municipality: "City of Gothenburg's service plan for municipal internal services 2021-2023" it is set that the City of Gothenburg is currently undergoing one of their most extensive digitalization periods, where they aim to develop what they call a City Information Platform (CIP). This platform aims to create an easily accessible webpage that will consist of and provide all available information regarding the city of Gothenburg. This will benefit businesses, visitors, and citizens when they need to contact a specific department or get hold of information quickly. The city of Gothenburg makes it clear that this solution is going to be beneficial for the citizens but also for themselves. When gathering the available information in one place, it creates an internal affiliation between co-workers and an external simplicity in the communication. Work is also underway on a continuation of the plan for 2023-2025.

IRIS in Gothenburg demonstrates a number of projects that are linked to open data, citizen engagement and new services that have provided opportunities to develop, test and evaluate – for instance through Energycloud and VR/AR. The City of Gothenburg has also carried out a test pilot of a CIM-City Information Model (TT4), where FIWARE was included as a framework architecture and gave some positive result. This in turn has led to a development for the City of Gothenburg's joint CIP-City Innovation Platform, where open data will be published (See TT4 and IRIS Deliverable D4.6 : Integration of CIP in LH Cities). The effects of IRIS partners' close collaboration for the publication of open data and the development of platforms through partner meetings, Webinars and peer-to-peer meetings, have created a broad network of colleagues within IRIS, around Europe and nationally within Sweden. Through various lessons learned, the City of Gothenburg has now come a step further, and during 2021 and partially in 2022 Gothenburg City are building the requirements specification for a City Innovation Platform-CIP as a service. These include both technical requirement and organizational requirements, which is a breakthrough for building a smart city innovation ecosystem. There will also be new roles and interfaces for support and production organizations.

A collaboration for replication has also been initiated between the city of Utrecht and the city of Gothenburg, to concretely learn more about parking services for electrically charged parking spaces through virtual workshops and peer-to-peer meetings during 2021.

Perceived impact

To find out what perceived benefits and effects of the IRIS project and other big and complex city projects a workshop was held during spring 2021 together with the City Development group that contains several managers from different city administrations and companies. Two of the questions were: A. What are the long-term effects for your organization of the strategic innovation projects? B. What are the long-term effects for the City of the strategic innovation projects? The following benefits and effects were the result after the workshop in the Development Group:

- The projects give us knowledge and structure
- Strengthens the city's brand and attractiveness
- Development of thematic collaborations between technical administrations and science parks.
- Contributes to climate benefits
- The projects provide credibility and visibility for the city of Gothenburg in Brussels.
- Participating in the projects gives Gothenburg a greater opportunity to "take home funds" in the future, it shows that you are a player to be reckoned with.
- Strengthens policy work in Brussels
- Long-term financing for the city
- Properly communicated, they can internally be a showcase for our approach

And the following benefits and effects were the result after the workshop at JSP.

- Broad competence development and the opportunity for policy development
- External monitoring and increased visibility internationally
- Increased investment in the city, the region, and the EU
- The projects make it easier to create new projects
- Contributes to climate benefits
- Opportunity to build new and larger networks
- Attractive employer, number of spontaneous applications has increased since the projects started
- Contributes to SME development in the region, also in the EU

In autumn 2019 JSP had a small exercise together with our Gothenburg parties and asked them to answer three questions.

1. What does the IRIS project mean for you and your organization?
2. What do you want to learn more about?
3. How do you want to learn (from the project)?

The most common answers were:

1. Collaboration, innovation, development, financing, knowledge, international context.

2. The demonstrations, open data, other European markets, V2G, citizen engagement.
3. Expert groups, internal presentations, breakfast seminars, workshops, webinars.

7.3 Preliminary Results at the Lighthouse City Level

As the IRIS project is still running, it is still very early to start to expect a vast bulk of tangible results at the City level, particularly considering the slow-moving nature of city planning and development. However, there are promising signs that IRIS will achieve these concrete results in the medium to long term.

An example: Utrecht and Gothenburg have arranged workshops together within the framework of replication activities and knowledge exchange. There are partners in Gothenburg who wanted to learn more about Utrecht´s demonstrations of V2G and ISO15118, roll-out strategies of sharing infrastructure, data driven roll out strategies and Smart Charging Parking (sensors). As a concrete result, the Volvo-affiliated company Polestar, Chalmers and RISE have now been included in a EU project application for a potential collaboration for V2G; SCALE.

Through the IRIS project, opportunities have been created within the pilot area Campus Johanneberg to test innovative solutions in several energy areas such as storage and optimization together with a mobility service with focus on tenants. User-centered digital solutions in energy and VR/AR have also been implemented. These solutions have aroused great interest around the local environment, as well as the regional, national, and international environment JSP is reaching. At the city level, IRIS is now better known, and more and direct inquiries are being received regarding everything from study visits to recommendations on how and where politicians can contribute in to communicate good examples from IRIS. This has been a long process as the political government changed during the project period and major organizational changes took place within the city of Gothenburg Municipal.

It is expected that the final report of this project will contain more concrete results as longer time then has passed to allow development processes to come to fruition.

Green Gothenburg & IRIS

Green Gothenburg is part of Business Region Gothenburg which is a city-owned company. Their mission is to increase the national and international recognition of the Gothenburg region as a leader in environmental and sustainable development. Green Gothenburg is also a part of Smart City Sweden, which is a state-funded export platform and cooperation between Sweden and other countries for smart & sustainable city solutions. The mission is to increase interest in the region's smart and sustainable solutions and help companies achieve more visibility and to increase business contacts. The work also includes to strengthen international business for local companies and to attract investments and enterprises to the Gothenburg Region.

Green Gothenburg´s showcases are focused within five areas: Climate, Energy & Environment, Mobility, Digitalisation, Urban planning and Social sustainability and every area offers study visits. The study visits are usually arranged for delegations consisting of decision-makers both in the public and private sector that are interested in implementing smart and sustainable solutions in their local contexts and are looking for international business partners. Also, events for business contacts like meetings and seminars are arranged.

Through the IRIS project the City of Gothenburg/Green Gothenburg have showcased different demonstration projects within the project, which contributes to strengthen the City and others. This adds several dimensions of value for the Gothenburg innovation system, for instance knowledge, networking, new contacts and visibility, locally as well as internationally.

Since the Covid-19 pandemic started, Green Gothenburg has developed a Virtual Tour in collaboration with the IRIS project as a new way of showcasing smart city solutions in Gothenburg. The focus for the first virtual tour was Innovative and Energy efficient buildings where you can discover the smart sustainbility solutions in three buildings and buildning blocks in the Lighthouse district; HSB Living Lab, A Working Lab and housing cooperative Riksbyggen´s Viva. The virtual study tour can be carried out individually, but also through group-shared personal guidance, which has been much appreciated and aroused great interest during the pandemic.

7.4 Next Steps

The work ahead consists of bringing all of the demonstrators to fruition, that is, more or less continuous operation during an extended period of time, during which data can be collected for analysis and conclusions. Some of the demonstrators, particularly in the Citizen Engagement track are of a more discrete nature and data collection will be handled differently.

A parallel task consists of using the momentum created by the IRIS project within the City of Gothenburg to continue and intensify the work to become a truly smart city. The work in IRIS has engaged many people in the city organisation, but it still remains to anchor IRIS and its findings in the City's strategic management. In brief, the steps can be summarized as follows.

- Continued implementation and data collection of demonstrators
- Close collaboration with Gothenburg City groupings to achieve higher impact, dissemination, and upscaling within the City
- Advocacy work to strengthen the political will to continue the innovation process
- Use of learnings and recommendations from partners for developments such as; policy, projects and climate goals.

8 Annexes

Annex 1: Support from WP3 on the x.4 Business models and exploitation sections

Annex 2: T7.6.1 Innovation Challenge. Change of Scope – lessons learnt

Annex 1: Support from WP3 on the x.4 Business models and exploitation sections

Exploitable results

There are several solutions within IRIS Gothenburg that have started to explore business models and/or tested them in a real environment through their demonstrations. There is also a chain of external actors in the local, regional, and national innovation system who have taken part in disseminated lessons - results that have been communicated and packaged to arouse interest in more people who want to replicate or try an IRIS solution. In two cases, it is in very early innovation phases as actors within the city of Gothenburg and the nearby city of Mölndal, who wanted to take part in the lessons for, above all, energy and mobility solutions for potential upscaling and start projects. Colleagues within JSP, Göteborg Energi and others work as a bridge between the IRIS project's results and knowledge sharing to interested parties for upscaling within Gothenburg but also within the Västra Götaland region.

Year	Location	Solution/s
Planning	Mölndal Forsåker	Early innovation phase for V2G, storage in batteries, smart energy system, Mölndala/JSP m.fl.
Planning	Göteborg/Oklandsåsen	Early phase looking for smart district solutions, Gothenburg Municipal housing company Framtiden
2020	Göteborg/Västra Frölunda	EC2B has been replicated & implemented in an existing building complex in collaboration with the Gothenburg municipal housing agency Framtiden.
2020	Lund	EC2B have been implemented in the real estate “Xplorion” in Lund in collaboration with Municipality of Lund real estate company.
2020	Gothenburg/Fyrklövergatan	Energy storage with second life bus batteries from Volvo within an existing real estate, Stena Fastigheter & Battery Loop
Planning	Gothenburg house 38	Second life bus batteries from Volvo will be implemented in existing rea lestate, Riksbyggen/Gothenburg Energy/JSP
Planning	Gothenburg/Kviberg	Second life bus batteries from Volvo will be implemented in existing real estate, Riksbyggen/Gothenburg Energy/JSP

Planning	Gothenburg/Gibraltar	Second life bus batteries from Volvo will be implemented in existing real estate, Riksbyggen/Gothenburg Energy/JSP

D3.8 already described that an exploitation plan has the objective to make use of results for scientific, societal or economic purposes and to recognise the exploitable results and their stakeholders. The next step was to - together with WP3 leaders - arrange workshops during the spring 2021 to identify results with the use the KER template for IRIS. One workshop was carried out in 2018 together with WP3 leaders for second life batteries.

- TT#1 second hand batteries
- TT#2 PCM – Phase Change Material
- TT#3 MaaS-Mobility as a Service
- TT#4 Energycloud
- TT#5 Minecraft

Annex 2 T7.6.1 Innovation Challenge. Change of Scope – lessons learnt

According to the IRIS Grant Agreement: "An innovation challenge will be held to stimulate the development of new applications making use of the CIM data". Unfortunately, within the framework of the IRIS project, the city of Gothenburg was not able to localise enough data to proceed with the Innovation Challenge.

This document is intended to provide an insight to the complexities of using BIM data to implement an Innovation Challenge. It will summarise the lessons the city learned from the process and will also provide guidance to cities and administrations who plan to use BIM data in future applications.

This report is an addition to the D7.6 Launch of T.T.# 4 activities on City Innovation Platform and information services (Gothenburg)

Description in Grant Agreement

Task

The task 7.6 is described in the following way in Grant Agreement:

"T7.6 Demonstrating Transition Track #4: City Innovation Platform (M13-M60) [GOT (17PM), TYRENS (25PM), METRY (22PM), CHALMERS (10PM), RB (5PM), SP (5PM), CERTH (1PM)]

Cross-cutting ICT enables the integration of the above-mentioned solutions, maximising the profitability of the integrated infrastructure. To achieve this, open ICT-system and open APIs are necessary, providing the City information platform and meaningful data services serving households, municipality and other stakeholders, together allowing for the new business models that emerge in the Gothenburg lighthouse project. Gothenburg will demonstrate the following solutions.

1) Implementation of a CIM (City Information Model) pilot that facilitates city management and planning by including building information, infrastructure, geodata and planning data in the Johanneberg district

In a digital model of the city, decisions, documents and plans can be connected to geographic locations, and forecasts, taking benefit of the visualization and planning application innovations provided by combining GIS (Geographical Information Systems) data with BIM (Building Information Model) data and 3D data in a way that captures both existing and planned structures to support the Urban area with analyses and maps. An innovation challenge will be held to stimulate the development of new applications making use of the CIM data.

2) Development and implementation an "Energy Cloud" on the Chalmers Campus. Near real-time data from energy (electricity, heat, water) consumption will be collected, integrated and made available for further analysis, thereby opening up for new applications to optimise energy supply and management on campus. For instance, setting maximum power limits dynamically adapting to varying consumption, predicting energy use automatically, analysing energy mix and calculating resulting CO2 footprint and more. This refined data platform will open up for external App developers to tap into the data and create innovative energy services for pilot implementation within and outside of the district. Additionally, a connection with Gothenburg City's open data is foreseen to further enhance the scope and usefulness of potential applications. An innovation contest will be held to stimulate the development of new application making use of the Energy Cloud.

This task is closely linked to the work carried out in WP4 and will make use of those common features and structures that are developed within that work package. Main KPIs include: Number of new applications using the CIM (target: >5) and the Energy Cloud (target: >5), respectively. Peak shaving for the Chalmers Campus Area (target >80 % peak power reduction)."

For more information on the CIM pilot please see D7.6 Launch of T.T.#4 activities on City Innovation Platform and information services (Gothenburg).

Change of scope & lessons learnt

Problems with original task scope

According to Grant Agreement: "An innovation challenge will be held to stimulate the development of new applications making use of the CIM data".

The data in the CIM pilot is based on BIM data from infrastructure projects. During the work with the pilot, it has become evident that the procedures and structures for collecting this type of data is far behind, and the data that we have been able to collect is limited to three projects. In order to be able to save the data in the CIM it is necessary that projects follow the same requirements identified in the project, but unfortunately no project follow these requirements, since this has not been implemented as requirements from the start. For the projects Tyrens must "remake" the data to make it fit in the CIM. As the requirements have not been either approved by or implemented in the city, no project data will automatically fit into the CIM. Currently the amount of project data available in the CIM is data from one project, the Hisingen Bridge.

To obtain BIM data:

At the start of the project the IRIS project requested BIM data from the city departments that work with planned, ongoing and finished projects. Unfortunately, there was not as much data as we expected. The reference projects are the projects that could provide relatively good interesting data. In the beginning we also changed the guidelines towards our entrepreneurs, so that 3Dmodels should be supplied to us when existing, however it takes time for these guidelines to give results. These guidelines will only affect projects being purchased after those guidelines were in place, which was after the start of the IRIS project. On numerous occasions during the IRIS project we have asked for project data both internally at the Urban Transport Administration and in the entire city. A lot of time has been spent searching for and investigating potential data. The little data that we have found has turned out to be of little use in the CIM in combination with too much effort to put it there.

In addition to that the City has a hesitation on sharing this type of detailed data in such an easily accessible way. There is a fear that the data could be used in the wrong way, so if an Innovation Challenge would be held, it has to be with contracted developers who are not allowed to spread the data.

To share data:

To avoid the risk of not being able to share the data, the approach was to only share what is already official data. At first, we did not think that sharing official BIM data would be a problem or a risk, however as the project has shown how easily this BIM data could be accessed and used, the risks of malicious use also have become more evident. The reference projects "Hisingen Bridge" and "Masthuggskajen" are considered sensitive for security reasons. As of the third reference project, Kville, this could also be the case. Additionally, the data from this project will not become official until after the end of the IRIS project, which means that this data cannot be used. We have investigated what guidelines there are in terms of open and shared data and looked for support in those, but it turned out that we could not get much help from those guidelines either as they are a bit unclear. Thus, the result is that we do not dare to share the data from Hisingsbron or Masthuggskajen openly. We have also considered using project data from constructions which are not as sensitive, but generally that kind of project data is not as interesting and will not be very useful to share. For this data we think the effort of adopting it will be higher than the value.

The City of Gothenburg does not believe that it is useful for the city nor the citizens to proceed with the Innovation Challenge based on data from one single project. Before start spreading the data and developing applications based on the data it would be more useful to develop the procedures, requirements and means of collecting and saving data.

In conclusion we can state

- We were not able to share the interesting BIM data we got from our reference projects and despite our efforts to obtain similar and useable BIM data, no BIM data could be made available at any levels at the city of Gothenburg to use in the Innovation Challenge. Efforts were made both at the Urban Transport Administration, other various administrations at the city as well as external partners. Thus, alternatives solutions to replace the Innovation Challenge, for example involving end-users or service providers in a different way have been investigated thoroughly.
- Unfortunately, the data that was possible to share – and to use in the Innovation Challenge - was not interesting enough to give added value to the project.
- This lack of available data has shown us that the city needs to value this need for BIM data as a priority area in the Urban Transport Administration internal development for 2021 and indeed the whole city.
- Cities have barriers in sharing the data and unfortunately there are no guidelines or requirements for collecting and sharing data and therefore the processes do not move forward. There is a hesitation, and no one is willing to take the step to move further. The data is available but is only intended for use by the project. Thus, the data needs to be classed in the models so that it can be shared in the right way. Finally, the city needs to review how the digital models can be used in other phases of the project and in other parts of the administration.
- It is clear to us now that the scope of the Innovation Challenge was too narrow from the start. Unfortunately, this could not have been foreseen.
- The innovation jam/workshop conducted as part of the IRIS project highlighted and recognised the need of sharing BIM data.
- There is possibility to explore the future connectivity to the city's digital twin. See below.
- The city has implemented necessary actions to avoid this risk of taking place, but that we are now faced with this deviation because it's unavoidable as explained above.

New scope – lessons learnt

What is needed to implement a successful Innovation Challenge based on BIM data? This document is intended to provide an insight to the complexities of using BIM data to implement an Innovation Challenge. It will summarise the lessons the city learned from the process and will also provide guidance to cities and administrations who plan to use BIM data in future applications.

The following list contains questions and problems relating to different aspects; the digitalisation of the building process (Smart Built environment), digitalisation in the city (increasing the sharing and use of models within the city), using BIM as a tool in the city (organisation, new methods of working and the handling of sensitive data) and finally the conditions needed to implement an Innovation Challenge with BIM.

- Have in place clear guidelines for open and shared data. Identify what the cities need to do to be able to as well as dare to share data.
- Have in place clear procedures and structures for data collection.
- Identify clear requirements for saving data in the CIM.
- Identify how the cities can enable that their (BIM) data become accessible, thus enabling the data to be published and communicated
- Identify how the city provides their (BIM) data:
    - Is the data classed? For example, are the different data elements in the model classified according to sensitivity? Is some data more available than other data? Not as high risk? Not confidential?
    - If not, can the data be categorized? Perhaps not all data is the same?
    - Should there be a recommendation that cities categorize their data?
- Ensure there is adequate accessible and available data from construction projects, e.g. infrastructure projects, during the life of the project to be able to implement the Innovation Challenge (if indeed the Innovation Challenge is a part of a project).
- Broaden the scope of the Innovation Challenge so that it is flexible and can accommodate unforeseen problems.
- Secure that 3D models are supplied (when relevant)
- Identify who needs to be involved (which city administrations, project partners, industry, researchers etc).
- Identify the implications of NOT doing the Innovation Challenge. What does this mean for the city and for the project?
- Have a clear strategy as to WHY the city wants to implement an Innovation Challenge, how it relates not only to the city's strategies yet also to regional, national and EU strategies. This might call for a workshop with the stakeholders to discuss the goals and the impacts.
- Have very clear goals and objective on how the results/knowledge of the innovation challenge will be used in the city and/or project. For example, will it be a part of the future planning of the city's operations? Used for replication? Upscaling? Used to apply for funding?
- Plan to do an evaluation of the Innovation Challenge.
- Identify alternatives if the Innovation Challenge in the intended form cannot be implemented. For example, can a Digital twin with its access to current data be used to implement the innovation challenge? (See below, chapter 4).
- Identify what is needed to succeed with the implementation of the Innovation challenge. Workshops? Innovation Jams? Etc.
- Identify a clear process for the whole process of the innovation challenge.

Moving forward

- This report will be spread within the city's administrations who have use of this report, partners in the IRIS project, interested cities and the European Commission.
- The city of Gothenburg sees the advantages with a CIM and the possibilities a complete CIM can provide the city. Work on the CIM began as an activity in the IRIS project but the potential for the future use was evident. The work we have completed in IRIS provides a strong base for the continued work with BIM data.
- The city of Gothenburg has an ambition to create a joint work/platform for CIP.
- Digital Twin. In Gothenburg, many initiatives regarding digitalization are being implemented. One goal is to create a digital twin of the city. Having a digital copy of the city, connected to real-time data, will facilitate gathering, sharing and visualizing relevant information in one platform for planning, control and maintenance. The Digital Twin can also serve as a test bed for development and innovation striving to achieve the global sustainable development goals. There is overall a political interest in opening up data, because it increases transparency and stimulate innovation. Benefits would be improved planning and greater efficiency in execution, for instance improved logistics when building new houses or infrastructure. The major challenge is to handle security issues and abuse of certain data, which need further development.

The City of Gothenburg - Digital Twin

- In order to develop the concepts of CIM, digital twin and data distribution Gothenburg has deepened its understanding of FIWARE, which is the smart solution platform, launched by the European Commission and the major ICT players in 2011. FIWARE provides a set of public and royalty-free tools that ease the development of smart applications.
-

Impact on the IRIS project

The innovation challenge activities will need to be adjusted in the time plan in task 7.6.1 to incorporate the change of scope.

Impact on KPIs and monitoring of KPIs

The main KPI for the CIM pilot and the only KPI for the CIM pilot specified in Grant Agreement is: "Number of new applications using the CIM (target: >5)". This KPI will not be reached. Number of applications will be 0.

In deliverable D 7.6 some more KPIs have been identified. Below is a short version of the monitoring plan for all KPIs for the CIM pilot as it was described in Deliverable D7.6. An extra column is added to describe the impact on the monitoring of each KPI.

KPI (Description from D7.6)	When monitor (Description from D7.6)	How monitor (Description from D7.6)	Impact on monitoring
Ease of use for end users of the solution	Twice, M32-M33 and M45-M46	1:st time, in workshop with users responsible for new projects and users responsible for administration of data from projects. 2:nd time, through questionnaire given to third party developers that participate in the Innovation Challenge	Will only be measured the 1:st time M32-M33, in the workshop
Advantages for end-users	Twice, M32-M33 and M45-M46	1:st time, in workshop with users responsible for new projects and users responsible for administration of data from projects. 2:nd time, through questionnaire given to third party developers that participate in the Innovation Challenge	Will only be measured the 1:st time M32-M33, in the workshop
Quality of open Data	Once, M45-M46	Manual check	No Impact
Open data-based solutions	Once, M45-M46	Manual check, how many applications exist after Innovation Challenge	Can be measured, but we already know that the target of >5 applications cannot be reached. We know the result will be 0 applications.
Usage of open source software	Once, M45-M46	Manual check	No Impact

Impact on Costs
The change in costs will only affect the city's internal costs.

Impact on other Tasks
Task 9.5 will be affected since the monitoring of the KPIs will be affected according to the description of impact on KPIs and monitoring above.

Impact on the demonstration and evaluation of the two use-cases “Visualize your city” and “Kick start your project

The use-case “Visualize your city” cannot really be evaluated since we would need third party applications from the Innovation Challenge to do that. We can still demonstrate the ideas through the test implementation that has been done by Tyrens in Cesium 3D. There is no impact on demonstration and evaluation of “Kick start your project".