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 7.4

Launch of T.T. #2 Activities on Smart energy management and storage for flexibility (Gothenburg)

Work Package:	WP7: Gothenburg Lighthouse City demonstration activities
Task:	T7.4: Demonstrating Transition Track #2: Smart energy management and storage for flexibility
Lead Beneficiary:	Akademiska Hus
Due Date:	30 September 2019 (M24)
Submission Date:	18 February 2020 (M29)
Deliverable Status:	Final
Deliverable Style:	R
Dissemination Level:	PU
File Name:	D7.4_Launch_of_TT2_Activities_on_Smart_energy_management_and_storage_for_flexibility_Gothenburg.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
Löveryd	Per	Innovation leader at Akademiska Hus AB
Selberg	Peter	Riksbyggen

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
Kjellander	Matilda	RB
Van der Ree	Bart	LOM
Tsarchopoulos	Panagiotis	CERTH

Version History

Version	Date	Modifications made by
1	2019 04 15	Per Löveryd/Peter Selberg
2	2019-06-28	Per Löveryd/Peter Selberg
3	2019-11-12	Per Löveryd/Peter Selberg
4	2019-11-21	Per Löveryd/Peter Selberg
5	2020-01-28	Per Löveryd/Peter Selberg

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

This report explains the work to date to achieve the demonstrators under Transition Track #2 in Gothenburg in the IRIS project. This report covers four measures in the two sites: A Working Lab, owned by, Akademiska Hus, and Brf Viva, owned by Rikbyggen. The scope in TT2 is to demonstrate how we can improve the electric, heating and cooling systems. In this case we do it in pilot facility in the buildings AWL and Brf Viva. We expect to prove the better efficiency in electric, heating and cooling system in the buildings.

Demonstration of A 350 V DC building microgrid utilizing 140 kW rooftop PV installations and 200 kWh battery storage

Akademiska Hus has built a building called "A Working Lab" (AWL), an office building of approximately 12 000 m². AWL is an office building and an innovations arena for Akademiska Hus. One of the innovation projects is DC microgrid with PV and battery storage.

Over the last couple of years, products have gradually been adapted to run natively on direct-current (DC) supply, *e.g.* multimedia appliances, computers, LED lightning, etc. Yet, our power supply system in buildings remains as alternating current (AC) which means that it has to be converted from AC to DC before energizing the products, resulting in some conversion losses. By instead switching to local low-voltage DC (LVDC) supply, some of these conversion losses can be reduced, creating a more energy efficient supply system, while at the same time material costs can be reduced since some power electrics in the current products will be redundant.

An additional contributing factor to an efficient DC distribution system is the coupling with distributed generation (DG) of energy, such as solar PV that produces DC directly together with a local energy storage, typically electrical batteries running on DC. Already with these two additions, assuming DC coupling, some of the conversion losses are avoided. As the market segment for these two technologies have had a rapid price reduction the last couple of years, and more of this to come, direct DC supply will potentially gain more momentum as time passes. Furthermore, local market regulations are today designed to promote self-consumption of the generated energy, increasing the incentive for local energy storage's which can help to utilise more of the energy in-house. Local storages can also be used for better system resilience and aid during power outages to supply the absolute necessities. The number of batteries used as electrical storage for residential houses is growing fast with decreasing retail prices as one of the main drivers. The same development is also seen for the solar photovoltaic (PV) market with price reductions and with a 29% increase in installed solar PV capacity from 2016 to 2017 [2]. This is one of the main drivers for an increased interest in coupling of solar PV and batteries in LVDC networks.

The project has concluded the building phase and is in the operation from September 2019.

Experience today December 2019 shows that DC products are limited in the market and need to be developed. The transfer energy losses are not so big today to justify the DC systems (Will be evaluated in this project). But the development can be more rapid if more customers are prepared to switch to more DC systems. In the future it may be a mix between DC and AC systems depending on the purpose.

Demonstration of A 1700 kWh PCM (Phase Change Material) cooling storage.

AWL will have a peak power cooling demand around 350 kW. The power demand will affect the central cooling system and increase cooling power production. This will contribute to reduce the expand the central cooling system and also affect the electric peak.

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 in order to achieve energy-efficient buildings.

The purpose of PCM Cold Storage is to reduce the peak cooling power demand by storing cooling energy in Phase Change Materials (PCM) in a Thermal Energy Storage (TES). The project is in its testing period, but unfortunately the PCM tank has had construction problems and have delayed the project for AWL building but not for IRIS project. The goal of the project is to store energy during low-consumption hours and consume the energy during peak hours, to relieve the central cooling plant.

Experience today, December 2019, shows that PCM (TES) products are limited in the market and need to be developed together with the customers (Will be evaluated in this project). When the PCM technology has more customers then price will go down and become a good alternative to peak demand cooling machines.

Demonstrators in Brf Viva

In Viva, two demonstrations are launched: One concerning a low temperature DH system between the buildings in Viva, and one concerning the integration and evaluation of second-life bus batteries in a stationary application.

Preliminary results from Viva indicate that using second-life bus batteries stationary for storing locally produced solar electricity is fully possible, useful and can contribute to mitigating the environmental cost of automotive batteries on a systemic level.

Demonstrator	In a nutshell
#1 Demonstration of A 350 V DC building microgrid utilizing 140 kW rooftop PV installations and 200 kWh battery storage	Brief summary: In this demonstration Akademiska hus together with IRIS demonstrate how DC system can give advantages when local electricity is produced with (PV) and stored in battery systems.
	Expected impact The batteries are primarily expected to provide peak power shaving, as well as storing locally produced PV electricity. Secondarily, they can be used to buy and store electricity from the grid to use or sell later. The DC system will provide secure supply and in an energy efficient way.
#2 Demonstration of a low temperature DH 45/30 system for six buildings	Brief summary: This measure considers connecting the buildings in Viva with a low temperature heat transport network.
	Expected impact: A heating system with steady service, providing high comfort with a low amount of purchased energy.

Demonstrator	In a nutshell
#3 Demonstration of A 1700 kWh PCM (Phase Change Material) cooling storage.	Brief summary: The purpose of PCM Cold Storage is to reduce the peak cooling power demand by storing cooling energy in Phase Change Materials (PCM) in a Thermal Energy Storage (TES).
	Expected impact: The PCM storage are primarily expected to provide peak power shaving in the AWL building. It can also reduce the peak power in the campus cooling system KB0 system in the way that AWL building will have lower power demand.
#4 Demonstration of integration and evaluation of a 200kWh energy storage	Brief summary: This measure explores the re-usefulness of vehicle batteries in stationary applications.
	Expected impact: The batteries are primarily expected to provide peak power shaving, as well as storing locally produced PV electricity. Secondarily, they can be used to buy and store electricity from the grid to use or sell later.

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

Abbreviation	Definition
CIP	City Innovation Platform
DoA	Description of Action
EU	European Union
FC	Follower City
IS	IRIS Solution
KPI	Key Performance Indicator
LH	Lighthouse
LHCSM	Lighthouse City Site Manager
MaaS	Mobility as a Service
PoR	Programme of Specification
PV	Photovoltaic
RES	Renewable Energy Sources
TT	Transition Track(s)
WP	Work Package
LCC	Life Cycle Cost
DG	Distributed Generation
PCM	Phase Change Material
HTF	Heat Transfer Fluid
TES	Thermal Energy Storage

1 Introduction

1.1 Scope, objectives and expected impact

The scope in transition track T7.4 1,2,3 and 4) is to demonstrate how we can improve the electric, heating and cooling systems. In this case we do it in pilot facility in the buildings AWL and Brf Viva.

We expect to prove the better efficiency in electric, heating and cooling system in the buildings.

1.2 Contributions of partners

In these four measures in building AWL and Brf Viva the following partners contributes to construction, building and operate the pilots.

Akademiska Hus is responsible for the demonstration track 2 but the leading of pilots it is split between Akademiska Hus and Riksbyggen.

ÅF infrastructure AB together with Chalmers University of Technology is responsible for the construction of PCM installation.

ÅF infrastructure together with RISE (Research Institutes of Sweden) AB is responsible for construction of the DC, battery and PV installations.

Byggdialogen, LG construction and SP group are responsible for demonstrations 1 and 3.

Riksbyggen is the responsible party for demonstrations 2 and 4.

Employees at Johanneberg Science Park holds coordinating functions for all of Riksbyggen's activities in IRIS, including this report.

Göteborg Energi is a close collaborator in all measures included in this report and have both provided input and material.

Chalmers, through several involved researchers, has made contributions to earlier versions of the descriptions that have been reworked into this report.

1.3 Relation to other activities

The two pilots for Akademiska Hus are related to each other because they are in the same building and works with energy storage. In the parallel project FED (Fossil free energy districts) the two pilots are connected to the tradingsystem I FED as two agents. The agents trade in cooling storage and electric storage. The pilots is also featured in WP1 Transition Track 1# and track 2#.

The two pilot for Riskbyggen are related to each other because they are in the same building: Riksbyggen brf Viva (Viva). Viva is also featured in other Transition Tracks, with the energy system in Viva having six measures in TT#1, and the mobility measures in Viva being covered in TT#3.

1.4 Structure of the deliverable

Chapter 2 explains the overview of the progress of the measure in the tasks that Akademiska Hus and Riksbyggen is responsible for. This chapter will serve as the backbone to the rest of the report and be heavily referenced to. Additionally, this chapter explains how the measures lead to Integrated Solutions in this transition track and/or in relation to the other transition tracks.

Chapter 3 explains the overall logic behind the selected baselines on demonstrator-level and measure level, as well as the quantitative baseline on demonstration-level. Furthermore, the drivers and barriers are presented.

Chapter 4 explains the organization for the pilot tracks.

Chapter 5-8 explain the various solutions in Akademiska Hus and Riksbyggen pilots and brings the conclusions for separate cases.

Chapter 9 presents the monitoring and evaluation approach at the Transition Track level.

Chapter 10 discusses the ethics requirements.

Chapter 11 shows the links to other work packages.

Chapter 12 covers conclusions and next steps which should be taken.

2 Demonstration in a nutshell

2.1 Ambitions for TT 7.4.1, T7.4.2, T7.4.3, T7.4.4 tasks

At campus Johanneberg, Akademiska Hus owns and manages a large portion of the buildings that provide premises for the university's operations. The AWL-building will act as a centre of innovation project for Akademiska Hus. Already in construction, new and innovative solutions and technologies are tested and demonstrated, e.g. within energy. The ambition is to minimise energy losses between the solar panels, the battery storage and the utilise in fans, lightning and other equipment by implementing a direct current grid internally in the AWL building.

The ambition is to make a whole building that is innovative, and it is therefore seen upon as a lab environment, where Akademiska Hus together with tenants and researchers test and take part in the latest in research and development. The fact that the building will be certified according to the Eco-Building level Gold clearly shows that sustainability is in focus. Exciting and innovative architecture means, among other things, multifunctional and customizable and spaces will be created for collaboration and flexible workplaces. Opportunities for conferences, smaller workshops and maybe even so-called ALC-Active Learning Classrooms, where the latest in pedagogy can be used, will take place in AWL.

The building will be both public and private. Throughput is of great importance to creativity and the ambition is to maximize innovative collisions between people with different skills and backgrounds. The entrance plan will therefore be open to the university, the square and the ElectriCity bus. In the entrance, visitors will be greeted by a lively area with café, restaurant, meeting places and workplaces.

In pilot project T7.4, 1, the ambition is to demonstrate a DC system that is integrated with battery and solar cells. The system will show how such a system can be more energy efficient than normal AC system. In the pilot project T7.4,3 the ambition is to demonstrate how to store cooling energy in a PCM storage. This system will show a PCM storage reducing the cooling peeks. The pilots is in operation from September 2019. Akademiska Hus will evaluate the project in 2019/2020 for IRIS and for AWL. For the PCM project Akademiska Hus will take a decision in jun 2020 to start the stage 2 after the evaluation of step 1 is done. Step 1 is 200 kWh/50kW and step 2 600 kWh/150 kW.

The pilot project T7.4, 2, 4 are part of Viva where Riksbyggen has the ambition to demonstrate a positive energy sub-district consisting of 6 buildings (132 apartments) from May 2019. Riksbyggen will evaluate most demonstrators in Viva from June 2019, including all demonstrators in TT#2.

2.2 Demonstration area Akademiska Hus for T7.4.1 and T7.4.3

The demonstration area is at the new office building A Working Lab (AWL).

Figure 1. Aerial view of district Johanneberg, including the locations of AWL and Viva.

Figure 2 AWL building

In AWL building the pilot installation for the PCM project is placed in the old water reservoir for research water/building " Väg och vatten 2'' also called ''SB3".

The DC/battery/PV project is incorporated in AWL. PV is located in the roof of nearby building SB3 and on the roof of AWL.

Akademiska Hus wants to spread the knowledge to organizations in Sweden and to international companies and of course the IRIS project.

2.3 Demonstration area Riksbyggen Brf Viva for T7.4.2 and T7.4.4

In the direct vicinity to Chalmers campus Johanneberg in Gothenburg, Riksbyggen has finished the construction of a new housing cooperative, Viva, with a total of 132 apartments. Viva is the result from an innovation process, led by JSP and Riksbyggen and involved several local partners, e.g. Chalmers, RISE (Research Institute of Sweden), City of Gothenburg, the local energy utility Göteborg Energi, architects and consultants. The process was initiated in 2010 and two years later it was established as "Positive Footprint Housing" with all above-mentioned partners.

Figure 3, Brf Viva as seen from Johanneberg Science Park

Viva aims at being the most innovative and sustainable housing project in the country and an array of integrated solutions aiming at more renewable electricity generation, electric vehicles and Mobility as a service, energy storage, heating and cooling are performed in Viva and included in IRIS as demonstrators. Compare the sketch shown in Figure 2.

At this point, the entire Viva-complex has been sold by Riksbyggen to the housing association of Viva, including all six housing buildings and the joining/servicing building that hold bike garage, storage rooms for the apartments, energy central, battery room and common venues as a greenhouse and winter garden. Riksbyggen is still responsible for the maintenance and service during the first five years.

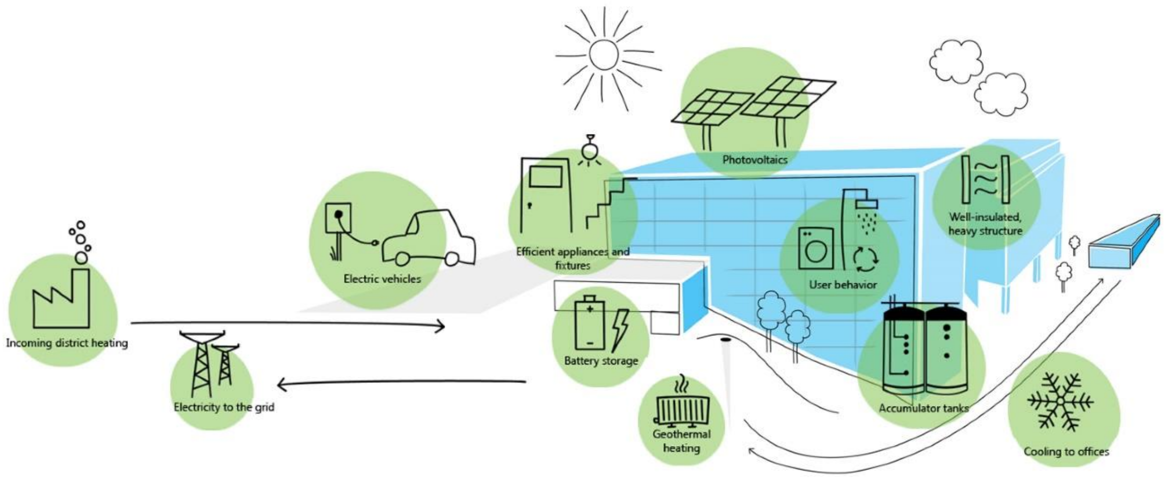

Figure 4. The components of the energy system in Riksbyggen's housing association Viva

The aim is to create solutions that enable a positive energy balance in districts and create an attractive, social inclusive campus and neighborhood.

2.4 Integrated Solutions in T7.4

Demonstrators 1 and 2 contribute to Integrated solution IS-1.1: Positive Energy Buildings.

Demonstrators 1 and 4 contribute to Integrated solution IS-2.1: Flexible electricity grid networks.

Demonstrators 1, 3 and 4 contribute to Integrated Solutions IS-2.2: Smart multi-sourced low temperature district heating with innovative storage solutions.

Demonstrator 4 contributes to Integrated solution IS-2.3: Utilizing 2nd life batteries for smart large-scale storage schemes.

2.5 Integration of Demonstrators

The demonstrations T7.4.1 and T7.4.3 in which both work with storage of energy in AWL building, but with different energy carriers, will integrate with each other and work to optimize energy storage. Both will be evaluated in Akademiska Hus's innovation group. Decision will be taken after the evaluation if the projects will be implemented in Akademiska Hus building process.

The demonstrators T7.4. 2 and T74.4 work in Viva, but with different energy carriers. They are also both intimately linked to other demonstrators in TT#1 in Viva.

2.6 Deviation according to the grant agreement

For the DC the voltage has change from 350 V to 760 V. The reason for that is that 350 V is not a standard today and 760 V fits better to the fans and other equipment that operate on the DC system.

Phase Change Material (PCM) layer in the A Working Lab (AWL) building is only 25% of the capacity as foreseen in the DoA in first step. In later stages in 2019-2021, this will be expanded gradually (estimated to reach about 50 % of the capacity originally planned). After the evaluation of step 1 we will be more secure what step 2 will be projected for. The cause for the deviation is that the PCM medium turned out to be more expensive than originally estimated in the project proposal. The consequences for the evaluation are small, since a proper performance assessment can be done already with the lower installed cooling capacity.

3 Baseline / Drivers and Barriers

3.1 Baseline

3.1.1 *Baseline for demonstrators T7.4.1 and T7.4.3*

T7.4.1: The cooling energy and peak demand in AWL was planned to be produced with the central cooling productions plant at Chalmers campus Johanneberg. To do so there was plans to buy new cooling machines for the peak power, which is considered the baseline. A new decision was made when a new solution with PCM storage came up. The PCM system was at the same time established in the IRIS project therefore Akademiska Hus decided to go on with the project.

T7.4.3: For the DC, battery and solar panel the baseline was that Akademiska Hus in AWL took a decision to have roughly 200 kW solar panels on AWL and SB3 building roofs. As for the DC, the baseline is considering to be AC, traditional, while the batteries are still unusual components in office buildings. To use the solar panel energy/power as effective as possible therefore were a new decision to build a dc/battery pilot in AWL building. This decision was taken at the same time as IRIS took their decision to do it to a demonstration in T7.4.3.

3.1.2 *Baseline for demonstrators T7.4.2 and T7.4.4*

Riksbyggen's Brf Viva is built on land that is previously undeveloped, in an area that is not very dense, although with quite high multi-family houses (3-10 stores). The area used to hold an open-air parking lot with around 20 parking spaces and a forested slope. Hence, the baseline for the project is no house at all.

Instead, a relevant baseline to compare with is a reference building that would have been built without all the innovation work that has been done for Viva, that simply follows national regulations.

For a standard, reference building, the highest allowed energy use is 90 kWh/m2 and year, according to the Swedish Board of Housing. A reference building would have an energy system without the demonstrators that are included in Viva in this TT.

3.2 Drivers and Barriers

Barriers and drivers can be discussed from several aspects: political, economic, sociological, technological, legal and environmental.

Political

Barriers
Subsidies for introduction of new technology can be complex and subject to political decisions and may therefore constitute a barrier for business model development and market introduction.

Drivers
The majority of the political parties in Sweden agree on the need for reducing GHG emissions, so there is unanimous political support for initiatives that will work in that direction. The political will has e.g. been

specified in the climate target that stipulates that the West Swedish economy should be fossil-free by 2030.

Economic

Barriers

It is difficult to quantify life cycle costs of systems and how large the savings are in reality. Market introduction may be hard for some technologies, especially TCM, where cooling machines have a strong market position today.

Large investment costs and long payback times for batteries and other storage options may act as a barrier for market introduction. However, higher efficiency, lower consumption and own production will lower the energy costs for property owners and residents.

Drivers

A flexible energy system will provide financial benefits by enabling storage of energy and shaving peak consumption, which otherwise often constitute the hours with the highest electricity prices on the spot market.

Sociological

Barriers

No sociological barriers can be seen.

Drivers

Champions and influencers in this field will create a positive social context driving the progress in the right direction

Technological

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.

It has been intensive effort to find a good solution for how the PCM tank should be built. Supplier for PCM storage system have been difficult to work with in the procurement phase and it has taken time in the project but has been I educational. To develop the optimal solution for the heat exchanger solution took a large part of the design time. However, developed solution is technically and economically well assessed.

Drivers

Technological development is moving fast in this field and this rapid development is a driver in itself. There is also a good opportunity for publicity when new technologies are implemented and tested in real life.

The close cooperation at campus between the property owners and researchers in various fields (often with Johanneberg Science Park as a facilitator) ensures the utilization of research's driving forces to transform good ideas into business opportunities.

Legal

Barriers

There is a barrier in the work of finding the right ways for collection, management, storage and ownership of different kinds of data. Usage is measured on household basis for the sake of individual billing, and usage data is to some extent shared for research, but beyond that it is still undecided. This could lead to data protection issues (advanced Energy Management System).

Fire safety regulations are not up to date for systems with reuse of bus batteries. Could prove inconvenient to comply with.

Drivers

Since Akademiska Hus own the nettwork, no special legislation applies for electric distribution in the campus area. Consequently, more DC system can be built.

Environmental

Barriers

There is still insufficient information on life cycle environmental benefits/costs for the whole energy systems.

Drivers

Flexible energy systems are crucial for the development and market penetration of renewable energy sources, which in turn provides environmental benefits.

4 Organisation of work

4.1 Akademiska Hus (T7.4.1, T7.4.3)

Akademiska Hus have organized the work with following companies and employees.

IRIS project	
Per Löveryd	Project leader for IRIS T7.4 and project leader PCM
Martin Söderholm	Financially responsible
Rene frydensbjerg	Control engineer
Jonas Hansson	Electrical engineer
Jelena Maric	Operations manager
Petrus Larsson	Operation engineer
Lars Lundahl	Operation engineer
Salaheldin Mohammed	Operation control enineer
Jan Henningsson	Project leader for AWL
Peter Karlsson	Innovationsleader for Akademiska Hus
Rebecka Gunnarson	Communicator
Kajsa Winnes	Communicator
Malin Ferm	Communicator
DC /PV/batteries	
Anders Lindskog	Rise DC /batteri consultant
Jan-Åke Borgelsson	Electrical consultant
Wideberg Lina	PV consultant
Fredrik Landen	Electrical entrepreneur
Leif	Elecrical entrepreneur
Bohlin Oskar	PV consultant
Anders Koppfeldt	Contruction manager
Mats Nilsson	Purchaser for materials
PCM cooling storage	
Angela Sasic Kalagasidis	Chalmers Professor Building technology
Pär Johansson	Chalmers bitr Professor
Pepe Tan	Chalmers PhD
Per Löveryd	Project leader
Lindberg Patrik	Energy consultant
Kaia Eichler	Energy consultant

Kristian Friman	VVS konsult projektansvarig
Jan-Åke Borgelsson	Energy manager consultant
Faruk Zelenjakovic	Control engineer
Martin Persson	Controlling entrepreur
Anders Koppfelt	Byggledare Bygg entreprenuar
Mats Nilsson	Purchaser produkts
Urban Kalin	Piplayer entrepreneur

Construction early and blueprinting

Angela Sasic Kalagasidis	Chalmers Professor Building technology
Pär Johansson	Chalmers bitr Professor
Pepe Tan	Chalmers PhD
Per Löveryd	Project leader
Lindberg Patrik	Energy consultant
Kaia Eichler	Energy consultant
Kristian Friman	VVS konsult projektansvarig

4.2 Riksbyggen (T7.4.2, T7.4.4)

Riksbyggen has been the actor throughout the development of Brf Viva. The activities relating to research and innovation have historically been located in a cross-disciplinary work platform called Positive Footprint Housing that Johanneberg Science Park is host, leader and organizer of. Riksbyggen is one of the earliest part-owners of Johanneberg Science Park, who have facilitated the contacts with various key people in academia and at the municipal government or municipally owned companies.

Currently, one main contractor, k21, has been procured in a partnership-type contract. They coordinate all the remaining work for technical consultants, technical controllers and the full array of sub-contractors. Riksbyggen remains the financer and has a large influence over purchases, among others.

Key personnel (Employed at Riksbyggen unless stated otherwise):

- Peter Selberg, research and innovation strategist at Johanneberg Science Park, funded by Riksbyggen. Task leader for T7.3 and coordinating Riksbyggen's IRIS-activities. Main author of this report.
- Matilda Kjellander, assistant project manager of brf Viva, and Riksbyggen's first contact on IRIS-issues beside economy.
- Patrik Hjelte, project manager of Viva.
- Charlotta Brolin, sustainability expert working with Viva.
- Anna Maria Walleby, sustainability expert focused on mobility.
- Mari-Louise Persson, national energy strategist.
- Mikael Ahlén, head of division.

- Anders Johansson, assistant head of division and previous project manager of brf Viva.
- Maria Hedlund, economist and Riksbyggen's contact on economic issues.
- Pierre Hult, Max Green and Robin Dunborg, energy engineers
- Helena Nordström, R&D Project Manager at Göteborg Energi, involved in most demonstrators in work packages 7.3 and 7.4.

Sub-contractors involved:

- Peter Fredriksson, k21, construction project manager in a partnership agreement with Riksbyggen. Coordinates the technical consultants, as well as the circa 80 sub-contractors who carry out the actual construction.
- Leif Gustafsson, construction site manager. Coordinates construction work and assists greatly during study visits to the site to ensure safe passage for visitors as well as keeping the construction on schedule.
- Emma Lund and colleagues at Trivector / EC2B, developing the mobility service that houses the e-vehicles which are being charged by the energy system of Viva.
- Researchers: Francis Sprei, Associate Professor at Chalmers, studies mobility patterns of the coming residents of brf Viva. Ulrika Holmberg, PhD, and Sandra Hillén at the Centre for Consumption Science at the University of Gothenburg studies the residents' perception of the sustainability-oriented solutions in brf Viva.

Johanneberg Science Park is involved with the coordination of IRIS-activities in Gothenburg, RISE is included in the evaluation of the demonstrators (WP9). IMCG are involved for project assistance.

5 Demonstration of a 760 V DC building microgrid utilizing 171 kW rooftop PV installations and 200 kWh battery storage

5.1 Specification of the measure

In this demonstration Akademiska Hus together with IRIS demonstrate how DC system can give advantages when local electricity is produced with (PV) and stored in battery systems.

Battery and PV produce and use basically DC before we today transform it to AC. If Akademiska Hus can skip the transforming part DC to AC we can get a more efficient system.

The market for DC products is small today. In this project we will test how the market can deliver the products and how much effort in investment and working hours it takes.

In this demonstration we will measure the energy efficiency for production and consumption of electricity in AWL building. We will measure and compare DC and AC efficiency. When we have all data, we will finish with a LCC calculation.

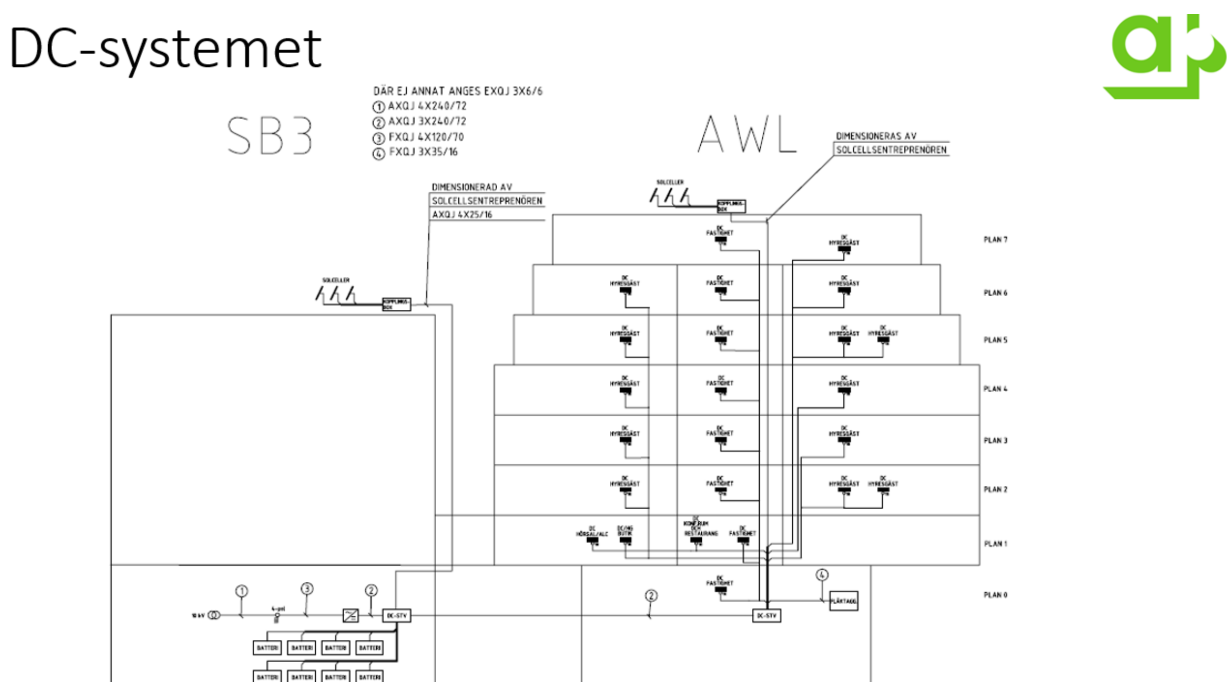

Figure 5 DC/ solar panel and battery system

5.1.1 *Hardware*

171 kW PV

200 kWh battery with maximum effect of 120 kW, type NCA

760 V DC (between minus and plus pole) system for power to ventilation fans AWL and some parts of the lightning.

5.1.2 *Software*

The software is built into the devices. The battery/PV software is controlling how to distribute to the DC system. It also controls the battery charging and discharge.

Software used in the project:

Ferroamp

Webport

Wepfactory

Also the control system for AWL building is working together with PV/battery/DC systems.

5.2 Societal, user and business aspects

5.2.1 *Business model*

If the pilot after the evaluation by Akademiska Hus will be successful, the solution can be used in other Akademiska Hus buildings. Companies which is working in this area can take up the product in their markets. The business model is based on more efficient electric system in DC system when the building produce electricity with PV (Solar cell) panels since it takes away conversion between AC and DC, yielding approximately 3-5 % higher efficiency.

5.2.2 *Governance*

Akademiska Hus has the ownership and makes the final decisions in the AWL pilot project. For technical expertise and research development follow-up, Akademiska Hus collaborate with Chalmers University of Technology as well as consulting company ÅF.

5.3 Impact assessment

5.3.1 *Expected impact*

The pilots will contribute to demonstrate smart energy management and storage for flexibility in that they deliver demonstrators associated with the Iris project. It will deliver demonstration pilot as writing down it the Grant agreement.

With a successful implementation, we expect to see:

- Increased degree of self-sufficiency
- better understanding of the usefulness of stationary battery systems
- enabling a higher level of flexibility and ability to choose when to import energy to the building
- ultimately reducing peak loads and CO2 emissions.

5.3.2 *KPIs*

The following KPIs have been selected to assess the success and suitability of this measure in this context.

Table 1. Summary-list of KPIs and related parameters for Measure 1

KPI	Parameter(s)	Baseline	Target
Peak Load reduction with dc, battery and PV (solar panel)	Charging power to the batteries. [W]	Consumed electricity in the building minus the used PV electricity, which is what should have been bought without the battery and dc systems.	80% peak power reduction
	Charged electricity to the batteries. [Wh]		
	Discharging power from the batteries. [W]		
	Discharged electricity from the batteries. [Wh]		
Storage Capacity Installed in battery storage	Storage capacity in the battery [kWh]	0 kWh	200 kWh
Degree of energy self-supply by RES	Locally produced electricity kWh/year	0 kWh	10%
	Total consumption of electricity kWh/year		

5.3.3 *Monitoring plan*

When we in the project evaluate, we use the measurement system built in AWL building. The data will be stored in the measurement computer and the calculations will be in reports for IRIS and Akademiska Hus.

After completed contract September 2019 the systems will be tested out. It will probably be some operation problems in the start. The evaluations will be done by Akademiska hus and Rise. Data will be stored in Akademiska Hus system like Wepport, Energiportalen. Rise will use their systems. Evaluations meeting will be held every month for good follow-up of the project

The plan for activities

September start of the systems

October/November sort out operation problems

December start evaluation

May 2020 evaluation will end for step 1 (200 kWh). After the evaluation a decision will be made to proceed with step 2 (600 kWh) or continued development of step 1. The evaluation and testing will continue to December 2021.

5.4 Commissioning Plan

The projects are carried out according to Akademiska Hus quality systems and Swedish authorities' requirements.

The pilot project leader Jonas Hansson is an experienced manager and are involved in every step in the commission.

Table 2 Commissioning plan

Phase	Activity	Parties involved	Responsibility	Relevant standard
1 Design	Conduct cross-disciplinary innovation	Akademiska Hus Reis Ramböll consulting AB ÅF consulting AB	List of innovations to be included and demonstrated in AWL	N/A
	Make early design	Akademiska Hus Byggdialogen AB SP elgruppen AB Reis Ramböll consulting AB ÅF consulting AB	Preliminary drawings	• Swedish standards for housing and construction • Akademiska Hus AB guidelines for housing
2 Engineering	Develop drawings	Akademiska Hus Byggdialogen AB SP elgruppen AB Reis Ramböll consulting AB ÅF consulting AB	Detailed drawings	• Euro Codes for housing and construction • Fire regulations • Environmental certification at Sweden Green Building Council
	Sizing of the energy system	ÅF consulting AB Ramböll consulting AB Reis	Energy balance planning	
3 Contracting	Acquire coordinating contractor	Byggdialogen AB	Primary contract	
		SP gruppen AB	Electric system	

4 Realization	Oversee and coordinate work	Byggdialogen AB		
	Installation & connection of PVs	Solkompaniet AB		
	Deliver/install batteries and battery management system	Ferro amp AB		
	DC systems	SP gruppen AB		
5 Testing	Systems testing	Installation coordinator	• Control of how well technical systems fulfils specifications in drawings • Control of that the different systems communicate correctly	
	Technical inspection	Inspectors for areas, respectively; e.g. piping, HVAC, electrical, construction		
	Agency oversight	Fire brigade		
	Test of function	Representatives from all companies involved in realization of measure	Testing of all systems, sub-systems and components.	
6 Completion	Accept responsibility over maintenance	Akademiska Hus service and maintenance department	Accept responsibility over maintenance of • PVs • Batteries • DC system	

5.5 Implementation Plan

5.5.1 *Planning of activities*

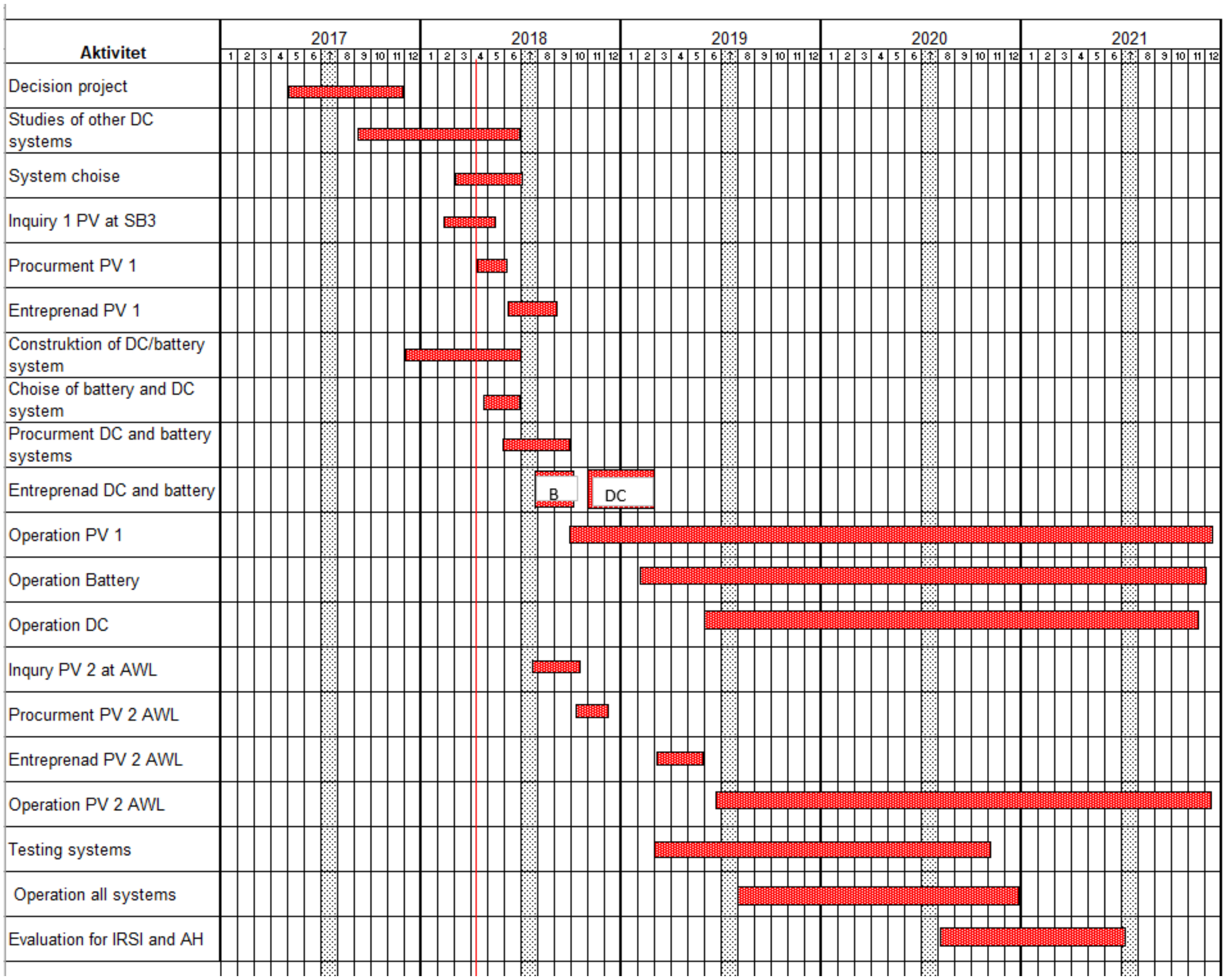

Figure 6 DC/PV/battery time schedule

5.5.2 *Planning of costs and (equipment) investments*

The costs in investment and working hours are in the budget for the pilot. The budget for IRIS is a part of the total pilot AWL budget.

In more detail, the total costs:

Consulting cost:	100 000 Euro
Akademiska Hus project management:	141 000 Euro
Battery system:	225 600 Euro
PV:	200 000 Euro
Electric installation	100 000 Euro

Control systems:	25 000 Euro
Construction:	100 000 Euro
Evaluation	25 000 Euro
The IRIS project finances	196 900 euro

5.5.3 *Risk management*

Risk management is in the normal Akademiska Hus routine.

The main risks will be the operation of the system between solar panels, battery storage and ventilation fans. There is also a risk that components in the system, such as ventilations fans not have so long service life. Its new product that have not been in the market before.

5.5.4 *Progress achieved up to M24*

In September 2019, the last building activities took place and the pilot is taken into the operation. The AWL building and the electrical system with DC/battery/PV system are mounted. Figure 6 is showing DC/solarpanal/battery time schedule.

5.6 Conclusion

An additional contributing factor to an efficient DC distribution system is the coupling with distributed generation (DG) of energy, such as solar PV that produces DC directly together with a local energy storage, typically electrical batteries running on DC. Already with these two additions, assuming DC coupling, some of the conversion losses are avoided. As the market segment for DC technologies have a rapid price reduction the last couple of years, and more of this to come, direct DC supply will potentially gain more momentum as time passes. One problem today is the lack of DC equipment on the market. The market must develop more products for DC systems and also maintain and develop AC products. This is a challenge for the industry. The development of AC systems also progresses in becoming more effective and will always be on the market. In the future the DC and AC systems will be installed in a mix or separately for most cost-effective solutions. Furthermore, local market regulations are today designed to promote self-consumption of the generated energy, increasing the incentive for local energy storages which can help to utilise more of the energy in-house. Local storages can also be used for better system resilience and aid during power outages to supply the absolute necessities. The DC systems may work better in self-consumption system then AC systems and gain market. In future the local production of electricity can grow much so exporting electricity will be more common. Then the transformation from DC to AC needs to develop.

Experience today, December 2019 shows that DC products are limited in the market and need to be developed. The transfer energy losses are not so big today to justify the DC systems (Will be evaluated in this project). But the development can be more rapid if more customers are prepared to switch to more DC systems. In the future it may be a mix between DC and AC systems depending on the purpose.

6 Demonstration of a low temperature DH 45/30 system for six buildings

6.1 Specification of the measure

This measure considers connecting the buildings in Viva with a low temperature heat transport network.

6.1.1 *Hardware*

- District heating tubing.
- Heat exchanger of 200 kW.
- Heatpumps. On the geothermal energy, the condensor power is 205 kW total, or three times 65 kW, and CoP is 3.2. For the hot tap water, the condensor power is 90 kW total, or three times 30 kW, and CoP exceeds 3.75.
- Assorted vents, filters, tubes, connectors etc.

6.1.2 *Software*

To connect and control these, there is an overarching software infrastructure. This control system is improved in the demonstrator outlined in chapter 10 in D7.3.

6.2 Societal, user and business aspects

6.2.1 *Citizen engagement*

The association of Viva is the owner of Viva, and are the board of the association, when formed, will get continuous updates from the energy engineer employed by Riksbyggen. These updates will cover all innovative aspects of Viva but focus primarily on the energy system.

Through the parties in Riksbyggen's collaborative research and innovation platform Positive Footprint Housing, the work and the solutions in Viva are getting substantially larger coverage in communications nationally and internationally than other housing project in Riksbyggen.

6.2.2 *Business model*

This contribution of this demonstrator makes the entire heating system work with higher efficiency. The heating system is intended to primarily be run by the geothermal heat pumps which utilize heat in the around 8 °C cold water to heat up water in the main energy central up to a maximum of 45 °C in the main energy central. From there, it is transported to three sub-centrals, one for each pair of buildings in Viva, through the 45/30 °C low temperature DH-network. From the sub-centrals heat from the water can either be stored, used for heating or to heat up tap water. Additional heat pumps are used to heat tap water further to desired temperatures.

6.2.3 *Governance*

During the project period of IRIS, Riksbyggen will hold the contract with the association for maintenance and service of the facilities in Viva.

6.2.4 *Monitoring plan*

The energy system in its entirety will be monitored and evaluated, primarily within the scope of TT#1 and as described in D7.3. However, for this individual demonstrator, it is not possible to construct a baseline for meaningful assessments.

6.3 Commissioning Plan

The procedure is rather simple: Detailed drawings and instructions for the building are produced. The building is constructed. A third-party controller reviews the finished result and compares it to drawings, checking for built form and function. If there is any discrepancy, the constructor in charge of that particular piece of the building has to keep working to deliver the promised results.

6.4 Implementation Plan

6.4.1 *Planning of activities*

No more activities are planned.

6.4.2 *Planning of costs and (equipment) investments*

No more investments are foreseen.

6.4.3 *Progress achieved up to M24*

The system is entirely installed and running.

6.5 Conclusion

Everything is running as planned.

The only difficulty is defining a way of assessing the success of the demonstrator. Since it is such an integral part of the energy system of Viva, it is difficult to find a way of quantifying the result of this individual measure.

7 Demonstration: 200 kWh PCM (Phase Change Material) cooling storage

7.1 Specification of the measure

AWL will have a peak power cooling demand around 350 kW. The power energy demand will be produced in the central cooling system. The central cooling system consists of three electrically driven cooling/heat pumps and two reheat driven absorbing cooling machines. When a new building is connected to the cooling system it is generally needed to build more cooling capacity. But if the system can produce cooling to a storage when demand is low, the stored cool can be used in 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 PCM Cold Storage is to reduce the peak cooling power demand by storing cooling energy in Phase Change Materials (PCM) in a Thermal Energy Storage (TES).

The PCM storage is loaded from Chalmers campus cooling system KB0. It is discharged to AWL KB11 return pipe system. Temperature in KB0 system is in loading 7 C. Discharging from PCM is done at 14 C. KB11 inlet temp is 12 C and return temp 18 C.

In this demonstration we will measure the energy efficiency in cooling storage in a PCM material. Efficiency is measured in storage loses and in investment cost. The market for PCM product is small today. In this project we will test how the market can deliver the products and how much effort it takes. We will measure the energy efficiency for storage cooling capacity. We will measure and compare it with a cooling machine. When we have all data, we finish with an LCC calculation.

7.1.1 *Hardware*

In the hardware we have:

200 kWh, 50 kW PCM (Salt) storage step 1. After evaluation we start step 2 in increasing PCM storage to 800 kWh/150 kW.

The phase change material is a salt hydrate with a melting temperature of around 14°C and a solidification of temperature around 10°C.

The PCM material (Salt hydrat) is stored in a container ca 10 m3. Heat exchangers is in container and the PCM material I around the exchanger. PCM is filled in the container in liquid phase.

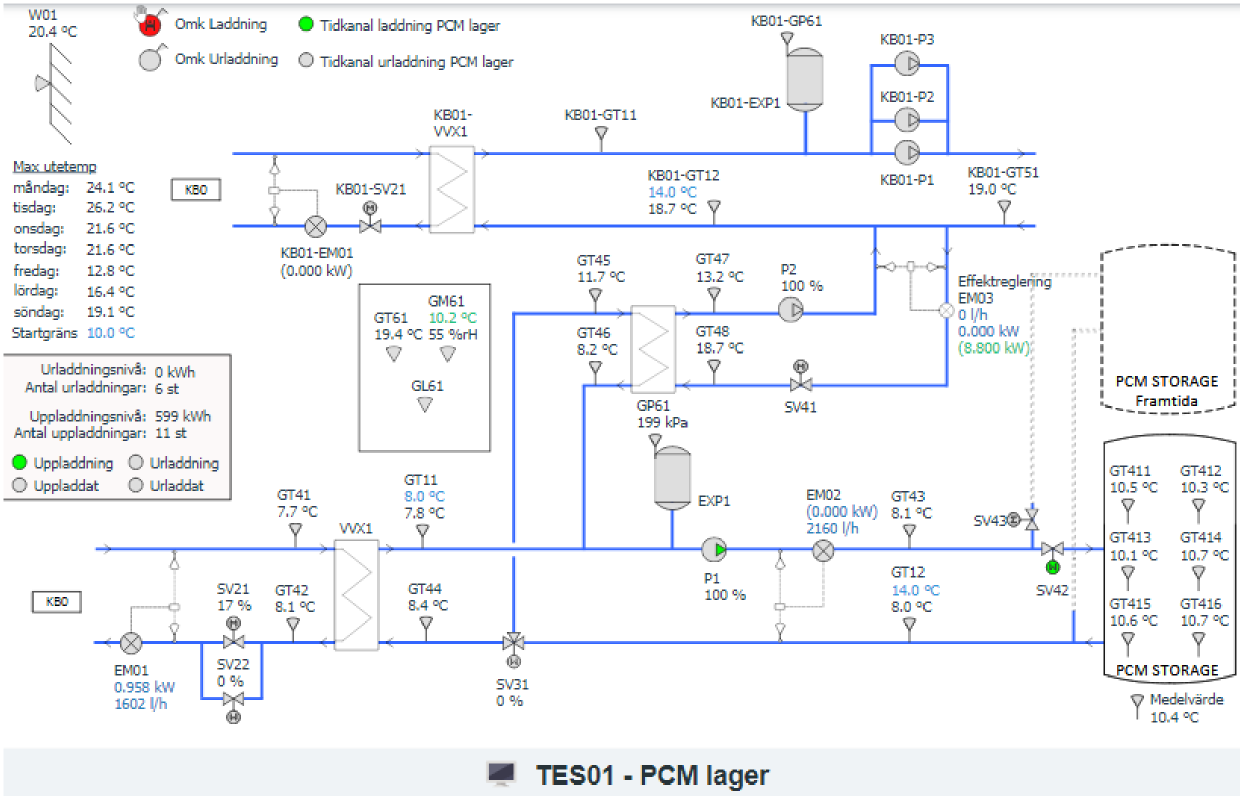

Figure 7 Principle of PCM storage

7.1.2 Software

PCM has its own PLC (Ventab) system for controlling. The system is monitored by an DHC system Webport.

The EU project FED can also remote operate the PCM cooling storage through a separate Webport/Webfactory system

7.1.3 ***Procurement of equipment***

The procurement for PCM made in competition with three manufacturers.

Table 3 presents the suppliers that were part of the enquiry regarding the TES for AWL:

Table 3 – Suppliers that were part of the enquiry regarding the TES for AWL

Supplier	Material (PCM)	Storage (TES)
PCM-Products	Yes	Yes
Rubitherm Technologies GmbH	Yes	Yes
Croda	Yes	Yes, through third party
Sunamp	Yes	Yes

Installation electric and plumbing done by project AWL contractors.

7.2 Societal, user and business aspects

7.2.1 *Business model*

If the pilot after the evaluation by Akademiska Hus will be successful, the pilot can be in business in other Akademiska Hus buildings and around the world. To reduce cooling peak production/demand is important for potential customers in their effort to save effect and energy. Companies who are working in this area will take up the product in their markets and do business. Akademiska Hus have great influence in the real estate branch and can if the PCM pilot project is successful it affects the property market.

7.3 Impact assessment

7.3.1 *Expected impact*

The pilots will contribute to demonstrate smart energy management and storage for flexibility. PCM storage will demonstrate how to store cooling capacity in a more compact form of energy cooling storage. The PCM technology have advantages in more compact storage and more sustained temperature deliver then common water storage. The storage aiming to reach 200 kWh/50 kW and hopeful even to 600 kWh/150 kW after testing are clear. The big advantage in storing cooling energy/power is that we can store when the C02 emissions are low and take out cooling capacity when CO2 emissions are high in the electric system that supplies the electric driven cooling machines.

7.3.2 *KPIs*

The following KPI have been selected to assess the success and suitability of this measure in this context and to as final aim reaching the peak load target specified in Table 4. In the same table the parameters needed are defined.

Table 4. Summary-list of KPIs and related parameters for Measure 3

KPI	Parameter(s)	Baseline	Target
Storage Capacity Installed in PCM cooling storage	Output thermal energy from PCM storage	0 kWh	Target for step 1: 200 kWh/50 kW for 4 h Target for step 1+2: 800 kWh/150 kW for 4 h
Peak Load reduction	Output cooling energy power (kW) from PCM	0 kW	Target for step 1: 50 kW Target for step 1+2: 150 kW
	Electricity power used for cooling (kW) calculated from cooling production VKA machine		Target for step 1 25 kW (el) Target for step 2 75 kW (el)
Storage energy losses	Input cooling energy [kWh]	Losses from eq. water storage	
	Output cooling energy power from PCM [kWh]		

7.3.3 *Monitoring plan*

When the project is evaluated, the measurement system built in AWL building is used. The data will be stored in the measurement computer and the calculations will be in reports for IRIS and Akademiska Hus.

The evaluation will start after the PCM plant is tested out. Today, December, the testing is finished and the evaluation is started.

The plan for activities

September testing

October to May evaluation and decision for step 2.

June- September construction of step 2

October start testing step 2

7.4 Commissioning Plan

The commission plan involves companies and employees, see below.

The pilot project leader Per Löveryd is involved in every step in the commission.

Phase	Activity	Parties involved	Responsibility	Relevant standard
1 Design	Conduct cross-disciplinary innovation	Akademiska Hus AB Byggdialogen AB LG Contracting AB Chalmers University Rise ÅF consulting AB Rubitherm AB	List of innovations to be included and demonstrated in AWL	N/A
	Make early design	Partners in PCM pilot project. Akademiska Hus AB Byggdialogen AB LG Contracting AB Chalmers University Rise ÅF consulting AB Rubitherm AB	Preliminary drawings	Swedish standards for housing and construction Akademiska Hus AB guidelines for housing
2 Engineering	Develop drawings	Akademiska Hus AB ÅF consulting AB Chalmers University	Detailed drawings	Euro Codes for housing and construction Fire regulations Environmental certification at

				Sweden Green Building Council
	Sizing of the energy system	ÅF consulting AB	Energy balance planning	
3 Contracting	Acquire coordinating contractor	Byggdialogen AB LG Contracting	Primary contract	
4 Realization	Head contractor	Byggdialogen AB		
	Installation & connection of PCM	LG contracting AB		
	Deliver PCM	Rubitherm AB		
5 Testing	Systems testing	Installation coordinator from Byggdialogen AB	Control of how well technical systems fulfils specifications in drawings Control of that the different systems communicate correctly	
	Technical inspection	Inspectors for areas, respectively; e.g. piping, HVAC, electrical, construction		
	Test of function	Representatives from all companies involved in realization of measure	Testing of all systems, sub-systems and components.	
6 Completion	Accept responsibility over maintenance	Akademiska HUS AB service and maintenance department	Accept responsibility over maintenance of PCM storage	

7.5 Implementation Plan

7.5.1 *Planning of activities*

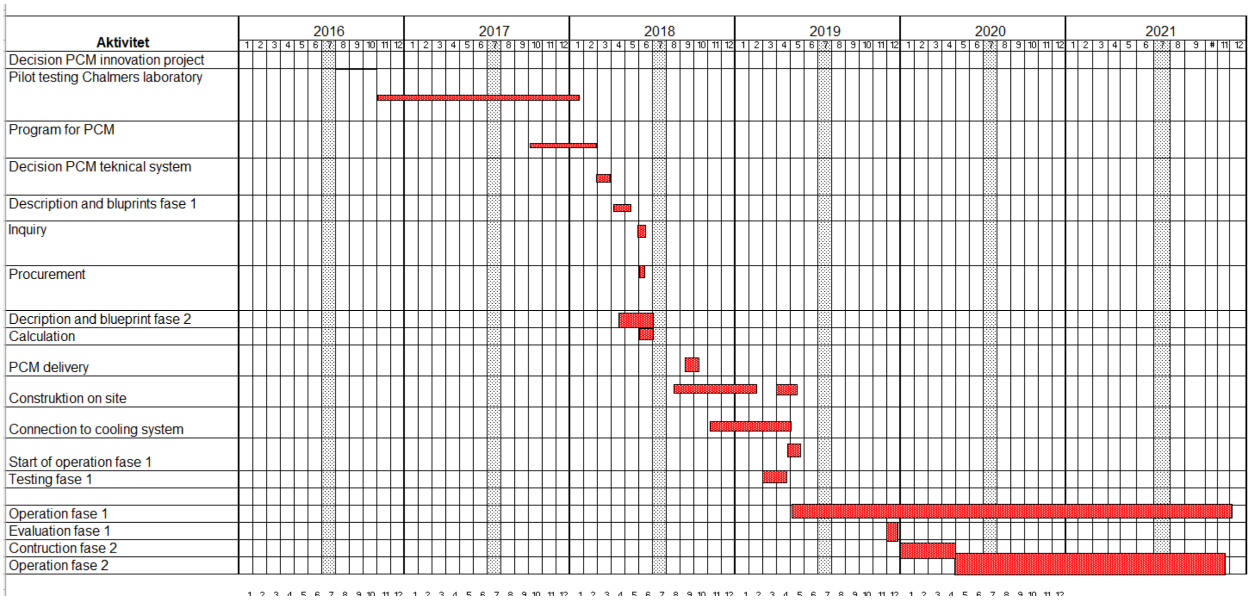

Figure 8. Time schedule

7.5.2 *Planning of costs and (equipment) investments*

The costs in investment and working hours are in the budget for the pilot. The budget for IRIS is a part of the total pilot AWL budget.

In more detail the total costs:

Consulting cost	25 000 Euro
Akademiska hus' project management	141 000 Euro
PCM storage	55 000 Euro
Plumbing installation	35 000 Euro
Electric installation	15 000 Euro
Control systems	25 000 Euro
Construction	30 000 Euro
Evaluation	25 000 Euro
The IRIS project finances	170 000 Euro

7.5.3 *Risk management*

Risk management is in the normal Akademiska Hus routine.

The Akademiska Hus risk management is always in all project and done before start message is given.

The main risk is that the PCM material does not reach the energy and power performance promised.

7.5.4 *Progress achieved up to M24*

Akademiska Hus is now in the last building activities for the pilot. The AWL building and the PCM has been taken in operation in September and now is under in evaluation.

Decision-making process

The following is a description of the design process of TES for AWL. During the project, Chalmers University of Technology, ÅF and Akademiska Hus has had a continuous collaboration for the development of a PCM Cold Storage.

Initially, a heat exchanger was to be built for the project by the project group. This was to obtain a product less expensive than available on the known market. The exchanger was planned to consist of stainless steel with a paraffin-based PCM and a capacity of 375 kW. The power output was chosen to cover the entire cooling demand of AWL during a hot summer day. Paraffin was chosen as the PCM since the only to us known TES plant was built with salt hydrate. This was a plant located in Kinna, which had known difficulties.

The calculations of the TES indicated that it would be an overly expensive construction and thus were rationalized to 75 kW and thereafter to 50 kW. After concluding that it would be expensive to build the TES, suppliers who could deliver a complete solution was searched for.

A discussion was conducted with a supplier who was able to deliver a TES at a price in line with a self-produced TES would cost. The supplier’s product had a power output of 75 kW which would have been higher than the self-produced. However, this TES used PCM consisting of a salt hydrate.

The supplier had a reference project in Norway that was contacted. That project presented a working solution, with no signs of leakage or other known problems. Consequently, it was decided to proceed with the supplier. However, due to communication difficulties, the trust against the supplier was lacking.

During the discussion, another supplier, Rubitherm Technologies GmbH, developed a separate solution for a TES. This TES was about the same price as the previous supplier.

Suggested PCM was paraffin-based RT10HC. The RT10HC has a solidification temperature of 8°C, which the KB0 after exchanger was deemed unable to deliver. Thus, the choice fell on SP11 (salt hydrate).

The initial plan was that the TES would run with a PCM that could deliver the same system temperatures as KB01 had at discharge. However, this did not succeed since no PCM that fitted was found. The challenge was that there were two defining temperatures – the charge temperature from KB0 and the discharge temperature of KB01. The decisive factor became the temperature which managed to cool the TES, according to the system conditions. Therefore, the temperature at discharge was lower than originally designed.

Transport options limited the size of our TES and it was decided to choose two smaller TES instead of one large. Further, it was decided to only order one to begin with to see how the TES performs.

7.6 Summary and conclusion

Akademiska Hus has decided to order together with project IRIS and project AWL a thermal energy storage (TES) with phase change materials with a cooling power of 50 kW and total energy capacity of 200 kWh from the supplier Rubitherm Technologies GmbH.

The phase change material is a salt hydrate with a melting temperature of around 14°C and a solidification of temperature around 10°C.

The goal of the project is to store energy during low-consumption hours and consume the energy during peak hours, to relieve the central cooling plant.

The project was tested in September before it got in the operation September/October 2019. The evaluation will be to Maj 2020.

After evaluation of step 1. 50kW / 200 kWh we will order step 2 150 kW/600 kWh.

The main aspects in the selection of the TES design are the cost and the area available. Larger TES generally provide more energy storage per invested money. Generally, there are two different types of TES used on the market. We have chosen to name them "Bulk storage" and "Encapsulation".

The bulk storage consists of a container filled with PCM and tubes with heat transfer fluid (HTF) transporting in and out of the thermal energy. The bulk construction can be carried out in different materials, usually steel or plastic. Steel has the advantage of better conductivity, but plastic is usually cheaper.

Some suppliers provide the possibility of having PCM encapsulated in different materials, usually plastic or steel. In a TES with encapsulated PCM, the HTF (e.g. water) flows freely through the tank and the encapsulated PCMs.

Conclusions from the work done until the time of the writing report can be summarized as following:

- To reach the target 1700 kWh as described in GA is not technically possible with the budget the project has available. Therefor the target has been set to the level within budget. Target 1/Step 1 is now 200 kWh and 50 kW.
- During the development of PCM storage has the choice of bulk storage landed in the choice of bulk storage because bulk storage are more leaking safe and gives significantly better heat transfer.
- The choice of manufacturer is carried out following a procurement procedure that takes into account price and technical qualities.
- During operation and simultaneous evaluation of storage capacities, problems have been discovered in how control of discharge and charging take place. New control algorithms have been added to improve the functions.
- Also, problems with reaching capacity have also been detected. Different solutions are currently being tested to solve the problems. One “simple” solution is to drain out more air from storage exchanger pipes to improve heat transfer. Another problem is that the PCM material separates so that the phase change changes according to the level in the PM tank.

8 Demonstration of integration and evaluation of a 200kWh energy storage

8.1 Specification of the measure

This measure explores the re-usefulness of vehicle batteries in stationary applications.

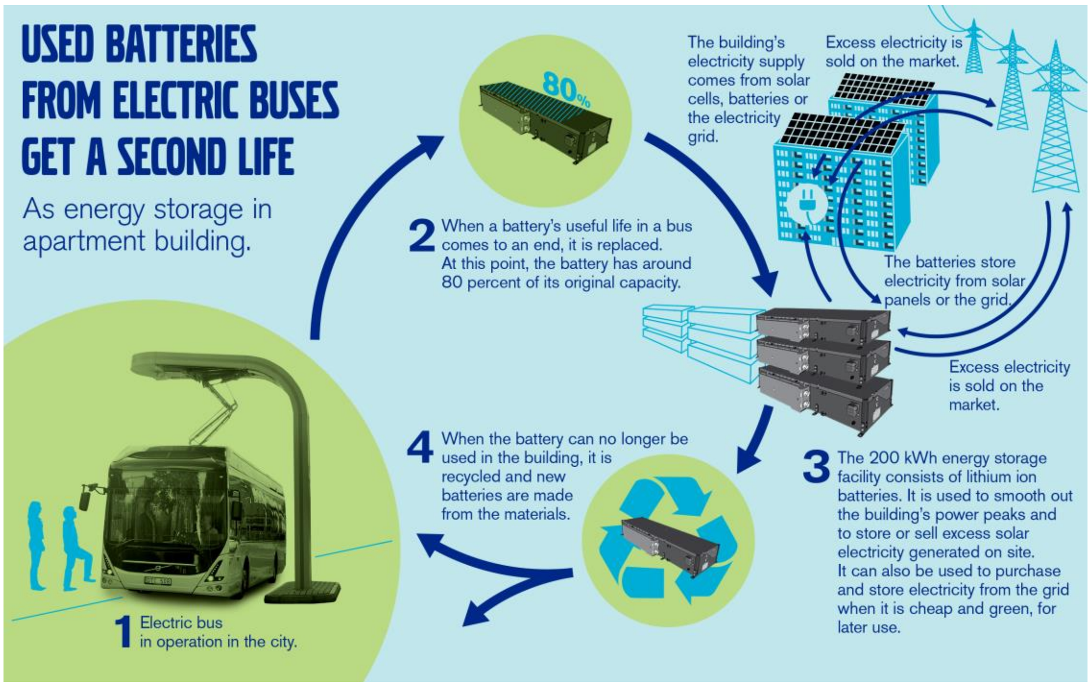

Figure 9. The circularity of the batteries

8.1.1 *Hardware*

The battery storage consists of 14 lithium ion batteries that have previously been used to power buses in public transport in Gothenburg. The specific chemistry is called LFP - Lithium FerroPhosphate, or Lithium-Iron-Phosphate. This chemistry offers a very low Cobalt content. The main ingredients are common metals including aluminum.

8.1.2 *Software*

The subcontractor FerroAmp, a small company delivering energy storage services to Viva, have developed their own control software. The subcontractor FerroAmp, a small company delivering energy storage services to Viva, have developed their own control software EnergyHub. This applies a self-regulated DC-nanogrid to connect the units and devices for efficient transmission. The EnergyHub then acts as the connector to the electricity grid. It also has two-way DC-AC converting. In Viva, it is programmed to keep the power outtake from the grid below a set level. This level is set manually, and preferably be updated along the seasons.

8.2 Societal, user and business aspects

8.2.1 *Citizen engagement*

The association of Viva is the owner of Viva, and are the board of the association, when formed, will get continuous updates from the energy engineer employed by Riksbyggen. These updates will cover all innovative aspects of Viva but focus primarily on the energy system.

Through the parties in Riksbyggen's collaborative research and innovation platform Positive Footprint Housing, the work and the solutions in Viva are getting substantially larger coverage in communications nationally and internationally than other housing project in Riksbyggen.

Residents will see the total energy balance of Viva in their resident app, as well as being able to monitor the use of heating, water and electricity of their own household. Additionally, the app displays the households' use levels in relation to other households in Viva, to motivate progress.

Physical access to the battery room is limited to a few authorized technicians for safety reasons. However, the door between the bike storage and the battery room is fitted with a glass pane to allow visual access. There is also a light switch placed on the outside of the room to enable a view of well-lit second life lithium ion bus batteries. These may be small measures, but they come a long way to help the communication of this individual solution in Viva.

8.2.2 *Business model*

The performance demanded from batteries is quite different between stationary and mobile applications. Specifically, the demands for delivered power and energy density is substantially higher when servicing vehicles. Therefore, the batteries still have a lot of useful capacity when taken out of the busses. In this case, they were expected to still have 70-80% of their initial capacity. In fact, the batteries could have remained in mobile application for some time; the timing of the installation and the size of the storage was made to suit the demand of Viva.

The batteries are primarily meant to shave the peaks off of the power supply to Viva, as well as storing locally produced PV electricity. Secondarily, they can be used to buy and store electricity from the grid to use or sell later.

In a future where more of the electricity is generated by sun or wind, the price will vary more from hour to hour. This creates incentives to shift the use to hours when the price is lower, following a larger availability of renewably produced power. And when the price of electricity changes, so does the production cost for district heating.

The batteries, and the storage and the flexibility that they bring, make it possible for a larger portion of the electricity that is generated in Viva to also be used in Viva. From calculations, it has been estimated that without the batteries 20 % of the PVs electricity would have to be sold. Only 4% of the same electricity have to be sold when including a 200 kWh energy storage in the calculations.

This stationary application of the batteries is a perfect example of the type of extended service life that vehicle manufacturers like Volvo are seeking to improve the value and overall sustainability performance of their products.

8.3 Monitoring

8.3.1 *KPIs*

The following KPIs have been selected to assess the success and suitability of this measure in this context.

Table 5. Summary-list of KPIs and related parameters for Measure 4

KPI	Parameter(s)	Baseline	Target
Peak Load Reduction	Used electricity [Wh]	Consumed electricity in the building minus the used PV electricity, which is what should have been bought without the battery.	25%
	Purchased electricity [Wh]		
	Used PV-generated electricity [Wh]		
Battery Degradation Rate	Energy taken out from the batteries over time [Wh]	Zero degradation.	Degradation rate per energy taken from the battery and degradation rate per year.
	Time in use [years]		
	Load cycles of the batteries [-]		
	Storage capacity in the batteries [Wh]		
Storage Capacity Installed	Storage capacity in the batteries [Wh]	0 kWh	200 kWh

8.3.2 *Monitoring plan*

Will be carried out in close cooperation with the utility company GE who has access to most of the data through their work with the overall energy management system, see chapter 11 in D7.3. They are also part in IRIS and another cooperative research project dealing specifically with advanced energy management.

8.4 Commissioning Plan

The procedure is rather simple: Detailed drawings and instructions for the building are produced. The building is constructed. A third-party controller reviews the finished result and compares it to drawings, checking for built form and function. If there is any discrepancy, the contractor in charge of that particular piece of the building has to keep working to deliver the promised results.

Table 6 Commissioning plan for Measure 1

Phase	Activity	Parties involved	Responsibility	Relevant standard
1 Design	Conduct cross-disciplinary innovation	Partners in PFH; Riksbyggen, Johanneberg Science Park, Chalmers, Gothenburg Energy, The Municipality of Gotheburg, RISE, Gothenburg University, consultants, contractors…	List of innovations to be included and demonstrated in brf Viva	N/A
	Make early design	Architects, Riksbyggen	Preliminary drawings	• Swedish standards for housing and construction • Riksbyggen's guidelines for housing
2 Engineering	Develop drawings	Riksbyggen and hired consultants, designers and engineers	Detailed drawings	• Euro Codes for housing and construction • Fire regulations • Environmental certification at Sweden Green Building Council
	Sizing of the energy system	Technical consultant Bengt Dahlgren AB	Energy balance planning	
3 Contracting	Acquire coordinating contractor	Riksbyggen - k21	Primary contract	
		Riksbyggen – Gothenburg Energy	Secondary contract for energy trading with city grid	
		K21 - other subcontractors, Riksbyggen vetoes	Secondary contracts	
4 Realization	Oversee and coordinate work	Coordinating contractor k21	Make sure the building is prepared for installation batteries	
	Deliver batteries	Owner of batteries, Volvo Buses		
	Connect batteries	Installation contractor, Assemblin		

	Install battery management system Ehub	Supplier and developer of battery management system, FerroAmp		
5 Testing	Systems testing	Installation coordinator	• Control of how well technical systems fulfils specifications in drawings • Control of that the different systems communicate correctly	CE
	Technical inspection	Inspectors for areas, respectively; e.g. piping, HVAC, electrical, construction	When deviations occur, k21 conducts the corresponding sub-contractor to correct the work.	
	Agency oversight	Fire brigade		
	Test of function	Representatives from all companies involved in realization of measure	Testing of all systems, sub-systems and components.	
6 Completion	Accept responsibility over maintenance	• Riksbyggen service and maintenance department • Gothenburg Energy	Accept responsibility over maintenance of the batteries	

8.5 Implementation Plan

Besides monitoring and the kind of optimization and tweaking that is commonplace in the early phases of a buildings service life, all measures to get the system running have been made.

8.5.1 *Planning of activities*

Two years after start of service of the electricity storage, enough data and experience will have been gathered to have results of solar irradiation, the energy demand of the building, and the ability of the batteries to store energy.

The way and pace of the degradation of the batteries vary with time and are dependent on the way the way they are used. A separate project from IRIS will monitor and evaluate the batteries for five years.

After that, in 2023, the batteries will be recycled. Volvo is responsible for the correct handling of this. Although, if the batteries perform well enough, and have not deteriorated too much, they may well keep servicing Viva even longer.

At some point, the batteries still need to be recycled, which is regulated by the Battery Directive 2006/66. The actual recycling is done by a specialized company, contracted by Volvo who still owns the batteries. Today, mainly copper and aluminum is sourced from the batteries. Most of the included materials can unfortunately not be recycled better than to recover energy in very well-filtered combustion facilities.

8.5.2 *Planning of costs and (equipment) investments*

There are currently no planned purchases for this measure.

8.5.3 *Risk management*

Table 7 Risks and mitigation activities for Measure 1

Risk	Mitigation Activity	Probability	Impact	Comment
Fire in batteries	The room they are installed in has no other purpose and is fitted with all necessary safety equipment, such as alarms, smoke detectors, dedicated ventilation shafts that open straight into the outdoor air, and the room itself is built as a separate fire compartment.	Low	High	The lithium ion batteries of this specific type are not considered flammable or explosive.
Electrical shocks from batteries	Staff handling them must be trained accordingly.	Low	Medium	The batteries are connected with voltages reaching 700 V.
Emissions of health-threatening gases from the batteries	Keep the batteries cooled below 80 degrees Celsius, and no gases will be emitted.	Low	Low	The alarms in the room would be able to detect this.

8.5.4 *Progress achieved up to M24*

The batteries and all accompanying systems for control, management and safety are installed and running.

8.6 Conclusion

The installer of the PV was sometimes turning off the power from the PVs during their testing which was insufficiently communicated to other contractors on site, resulting in disturbances in their work.

It took longer than expected to get directions from the fire brigade on how to position signage and light alarms. It was not possible to engage them enough to get them to site for this purpose, since they are too heavily occupied with other tasks and confessed that there is an apparent risk of misplacement. This is important since the PVs could create a voltage in the buildings electricity system even if the main power from the grid is switched off. This is of interest in the case of emergency.

9 Summary on monitoring of KPIs

The two demonstrator sites have gotten differently far in terms of monitoring.

In AWL, the monitoring period begun in November 2019.

In Viva, the monitoring has begun sequentially with the construction of the three phases have being completed. As per June 2019, all phases of Viva are inhabited and can be considered to have entered the monitoring phase. For the demonstrators that have been launched, the monitoring has begun on time. Something that can be said for all the demonstrators in Viva is that the selected KPIs are still considered to be a fitting set to describe the performance and value of the respective demonstrators.

9.1 Expected impact

While ensuring a reliable, comfortable and efficient supply of electricity and heating for the residents of Viva and workers in AWL, the measures described in this report also contribute to these elements of an energy system desirable for the future.

- Increased system flexibility through the introduction of storage capacity improving solutions for both electricity and heating.
- Creation of valuable insights into the effects on energy systems at building and city scale that measures like these have.
- And, most importantly, a clear assessment of whether these measures contribute significantly to emission reductions that can help us avoid the worst effects of climate breakdown.

9.2 Aggregation of KPIs for Gothenburg

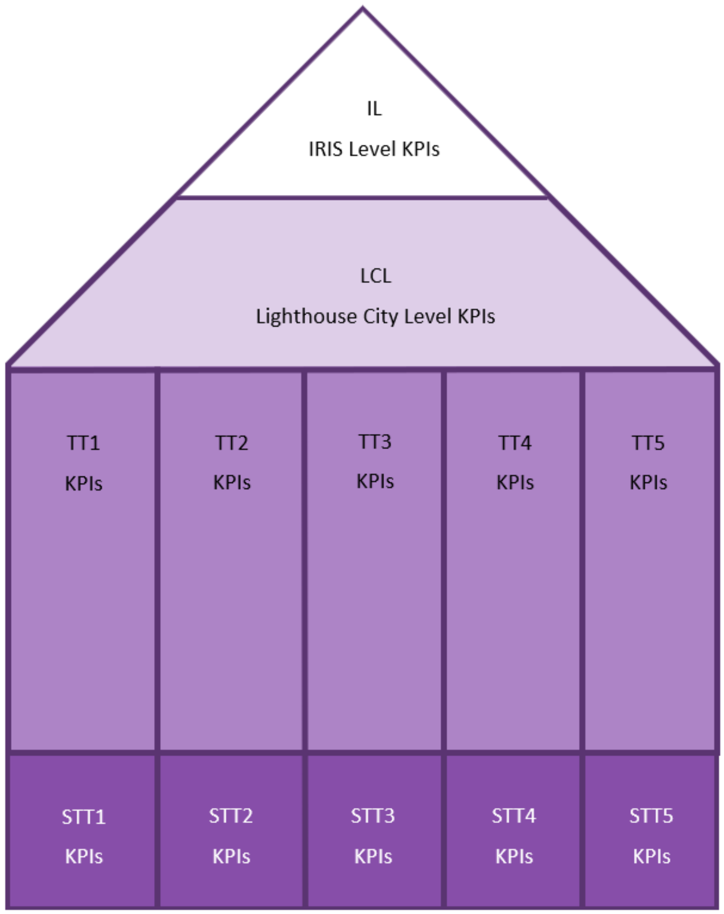

Figure 10. IRIS KPI-house.

9.2.1 *Gothenburg*

Table 8. Relation and possible aggregation of KPIs to solutions and the IRIS KPI-house in TT2

KPIs	Solution	Proposed position in IRIS KPI-house
Storage capacity installed	#1 Demonstration of A 350 V DC building microgrid utilizing 140 kW rooftop PV installations and 200 kWh battery storage #3 Demonstration of A 1700 kWh PCM (Phase Change Material) cooling storage.	TTL

	#4 Demonstration of integration and evaluation of a 200kWh energy storage	
Peak load reduction	#1 Demonstration of A 350 V DC building microgrid utilizing 140 kW rooftop PV installations and 200 kWh battery storage #4 Demonstration of integration and evaluation of a 200kWh energy storage	TTL
Battery Degradation Rate	#4 Demonstration of integration and evaluation of a 200kWh energy storage	SL

10 Ethics requirements

No specific ethical requirements are identified for this TT. Although there is activity in housing buildings, none of the activities include human participation.

10.1 GDPR compliance

GDPR does not apply for the demonstration activities in the measures described in this report as no personal information is collected.

10.2 Ethical aspects

No specific ethical aspects apply to these measures.

11 Links to other Work Packages

Both demonstrator sites that the measures in this report are deployed in, Riksbyggen's Brf Viva (Viva) and A Working Lab (AWL), have activities also in other Transition Tracks:

- The energy system in Viva has six measures in TT#1.
- The mobility measures in Viva are covered in TT#3.

Going forward, it would be very valuable to get increased support from WP3 for business modelling to facilitate replication and scaling up.

12 Conclusions and next steps

12.1 Demonstration of A 350 V DC building microgrid utilizing 140 kW rooftop PV installations and 200 kWh battery storage

The next step in the project is to test the system together with other systems in the building and between DC-battery-solar panels, When the testing is done the operation and evaluation will start.

So far the project will deliver the demonstrator in time. Problems in the construction of the system has been strenuous, but today´s results are good

12.2 Demonstration of A 1700 kWh PCM (Phase Change Material) cooling storage.

The next step in the project is to test the system together with other systems in the building and between PCM components. When the testing is done the operation and evaluation will start.

So far the project has delivered the demonstrator in part 1 and hopefully we can go to step 2 (more cooling storage) after the evaluation of part1.

12.3 Demonstrations in Viva

In Brf Viva the launch has gone about as smooth as hoped. The project has seen minor issues like miscommunications, unclear divisions of responsibilities, and other things that have been possible to deal with accordingly as the production of Viva progressed.

The next steps include monitoring and evaluation to answer questions such as:

- What are our experiences from the demonstrated solutions in Viva?
- What is necessary to achieve dissemination, replication or scaling up? If so, in which applications and on which terms?
- How to we continue working with the underlying issues that these demonstrators are an effort to find solutions to?