IRIS

Integrated and Replicable Solutions for Co-Creation in Sustainable Cities

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Launch of T.T.#1 activities on Smart renewables and near zero energy district (Gothenburg)

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0.8	8 November 2019	Final version for internal review
1.0	10 January 2020	Final version to be released to the EC by PC

Disclaimer

Executive Summary

This report explains the work to date to achieve the demonstrators under Transition Track #1 in Gothenburg in the IRIS project. This report covers seven measures in the two sites Riksbyggen Brf Viva and HSB Living Lab.

In Viva, demonstrations are launched covering: electricity storage in 2nd life bus batteries powered by local PV; heating from 200m-300 m deep geo energy with heat pumps; and local thermal energy storages. Demonstration is still under development covering: cooling from geo energy without chillers; bilateral seasonal energy trading with adjacent office block; and finally, the development and demonstration of advanced Energy Management System to integrate PV, DH, grid and all abovementioned storage options.

In HSB Living Lab, demonstrations are launched covering how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process.

This report describes all the measures individually, including software and hardware specifications as well as a general explanation of their purpose and scope. Also, non-technical aspects such as citizen engagement and business models are included, together with information of what and how will be monitored to assess how well the demonstration meet set expectations. All, if any, planned commissions, investments and actions are described to provide a useful overview before some conclusions into the work so far.

This document reports two very interesting findings. Preliminarily from Viva, 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. Decisively from HSB Living Lab, a facade consisting of Building Integrated PVs is not more expensive than an ordinary facade material when using thin film solar cell technology, and that solar cell technology is also better for the environment according to life cycle analysis.

For information into other measures that are being demonstrated in the same sites but relating to other transition tracks, it could be of interest to know that the energy system in Viva has two measures in TT#2, the mobility measures in Viva are covered in TT#3, and HSBLL houses one of the measures in TT#4.

Demonstrator	In a nutshell
#1 Demonstration of at least 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV	Brief summary: This measure is exploring the re-usefulness of vehicle batteries in stationary applications, together with solar PVs. The system is entirely installed and has begun servicing Brf Viva.
	Expected impact: Increased degree of self-sufficiency, together with 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. The size of the PV system has been increased compared to the original specification to around 170 kWp.
#2 Demonstration of heating from geo energy	Brief summary: This measure introduces heating of Viva by heat pumps drawing geothermal energy from deep boreholes. The system is entirely installed and has

Demonstrator	In a nutshell
with heat pumps (2-300 m deep boreholes)]	begun servicing Brf Viva.
	Expected impact: A heating system with steady service, providing high comfort with a low amount of purchased energy.
#3 Demonstration of cooling from geo energy without chillers	Brief summary: This measure is a system which circulates return water from the comfort cooling system of the office building CTP to the heating system in Viva, thereby transferring cooling to CTP.
	Expected impact: A cooling system providing high comfort to a low energy cost. Proof of the usefulness of bilateral DH-style connections of this kind. Greatly improved energy balance for both participating buildings, resulting in monetary savings for the association.
#4 Demonstration of local energy storages consisting of water buffer tanks, structural (thermal inertia of the building) storage and long-term storage in boreholes	Brief summary: This measure incorporates a couple of different thermal energy storages into the overall energy system of Viva.
	Expected impact: Increased thermal storage capacity, providing increased ability of flexibility, resulting in reduced peak loads and CO2 emissions
#5 Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block	Brief summary: This measure is a system which trades heated cooling water from the office building CTP, with cooled water from the boreholes in Viva.
	Expected impact: A cooling system providing high comfort to a low energy cost. Proof of the usefulness of bilateral DH-style connections of this kind. Greatly improved energy balance for both participating buildings, resulting in monetary savings for the association.
#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]	Brief summary: This demonstrator introduces an intelligent control system which will be installed and manage the power flows within the energy system in Viva.
	Expected impact: A management system that can consider multiple energy sources, storage opportunities and variables of value to optimize the usage of a building. This would be providing lower cost for the consumers, in this case the housing association, improved self-sufficiency on energy, and ultimately less carbon emissions from the city-wide energy system.
#7 Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process	Brief summary: This measure assesses the technical and economic feasibility of BIPV in renovation applications.
	Expected impact: Reduced energy cost as well as climate forcing when providing the residents of HSBLL with a comfortable indoor environment. Lower investment cost as well as reduced material use when adding PV systems to other buildings, when renovations would any way take place. Based on these two, a new renovation model for improving the energy performance of buildings.

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1.1 List of Abbreviations and Acronyms

Abbreviation	Definition
Brf	"Bostadsrättsförening", Housing Association
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
PV	Photovoltaic
RES	Renewable Energy Sources
TT	Transition Track(s)
WP	Work Package

1 Introduction

1.1 Scope, objectives and expected impact

The objective of this Deliverable is to provide a detailed overview of the launch of Gothenburg lighthouse interventions in Transition Track #1. This deliverable is intended for the following audiences:

- Stakeholders in the Gothenburg ecosystem as it should provide a detailed overview of the solutions that will be implemented by each of the partners;
- Stakeholders in the demonstration districts as it should provide them with overview of the solutions and on how local stakeholders will be involved;
- Project partners in the other lighthouse and follower cities;
- Broader public which is interested in the details of the demonstration.

1.2 Contributions of partners

Riksbyggen and HSB are the responsible parties for measures 1 through 6, and 7, respectively.

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 researchers involved in all measures, has made contributions to earlier versions of the descriptions that have been reworked into this report.

1.3 Relation to other activities

Both demonstrators / buildings that the measures in this report are deployed in, Riksbyggen's Brf Viva (Viva) and HSB Living Lab (HSBLL) , have activities also in other Transition Tracks:

- The energy system in Viva has two measures in TT#2.
- The mobility measures in Viva are covered in TT#3.
- HSBLL houses one of the measures in TT#5

1.4 Structure of the deliverable

Chapter 2 explains the overview of the progress of the measures in Viva and HSBLL. 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. However, the quantitative baseline on demonstrator-level is described demonstrator-by-demonstrator in the chapters 5-10.

Chapters 4 explains how the work has been organized, and who are the people who have been doing the main portion of the work

Chapters 5-10 explains the various solutions in Brf Viva.

Chapter 11 explains the solution in HSB Living Lab.

Chapter 12 explains the current state of monitoring of the selected KPI:s.

Chapter 13 explains ethics requirement and GDPR compliance.

Chapter 14 explains conclusions of the work thus far as well as the next envisioned steps in the project.

2 Demonstration in a nutshell

2.1 Ambitions for TT#1

Gothenburg's ambition is to extend further the already available positive energy district by integrating (a) a high share of locally produced and consumed renewable energy at district scale, (b) energy savings at building level, (c) energy savings at district level and (d) storage and transfer between buildings of surplus energy. In Riksbyggen demonstration area, it is not the individual elements of the solutions but rather their composition that will allow the future deployment of the proposed Solutions in larger areas. To build resilience and diversity in the self-sufficient energy system, several elements are designed to be applied, including those described in this report.

In this task, Gothenburg will demonstrate a positive energy sub-district consisting of 6 buildings (132 apartments). These buildings will be connected to a further 55 buildings on the Chalmers campus for trading surplus heating and cooling solar PV.

Gothenburg will also demonstrate how building integrated solar cells on the facade and roof of HSB Living Lab can be used within the renovation process. Six different BIPV facilities were installed at the HSB Living Lab to be able to compare and evaluate from a technical and economic point of view.

2.2 Demonstration areas

Both demonstrators are situated by the southern end of Chalmers campus Johanneberg in Gothenburg.

Table 1 Facts about the two demonstrator buildings

Building name	Brf Viva	HSB Living Lab
Building category	Multi-family house	Student apartments and living lab
Building owner	The housing association	HSB (private)
End of construction	May 2019	September 2017
Total floor area (m²)	11 200 m²	1 800 m²
Total height (m)	35 m plus foundation on the highest side.	16 m
Number of floors	11	5
Number of apartments	132	29
Energy target	Positive energy building, but still <24 kWh/m² before trading	60 kWh/m²
Energy system	District heating & geothermal heating	District heating & geothermal preheating of air(ventilation)
Cooling system	No cooling of apartments, but cooling planned to supply adjacent office building	No cooling system
Installed PV electricity capacity	170 kWp	50 m2 / 8.4 kW on the roof and 144 m2 / 10,12 kW at the façade
Type of storage system (capacity (kWh))	Electric battery (200 kWh)	Electric battery (7,2 kWh)
Involvement in IRIS demonstrators	1,2,3,4,5,6 in TT#1	7 in TT#1

2,4 in TT#2 1a) in TT#3	1b) in TT#3 ”3” in TT#5

2.2.1 *Riksbyggen's Brf Viva*

In the direct vicinity to Chalmers campus Johanneberg in Gothenburg, Riksbyggen has just 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 1 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 green house and winter garden. Riksbyggen is still responsible for the maintenance and service during the first five years.

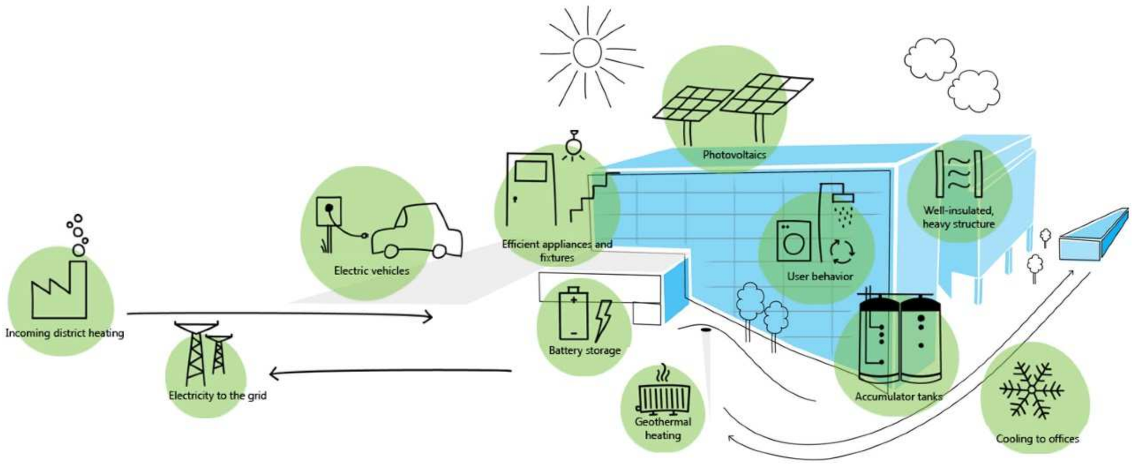


Figure 2 The components of the energy system in Riksbyggen's housing association Viva

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

In the Riksbyggen/Viva demonstration area, it is not the individual elements of the solutions but rather their composition that will allow the future deployment of the proposed Solutions in larger areas. To build resilience and diversity in the self-sufficient energy system, several elements are designed and will be applied.

The demonstrators included in transition Track #1 are:

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. This will be deployed in HSBLL.

2.2.2 HSB Living Lab

HSB has its Living Lab placed at campus Johanneberg. The Living Lab is the home for some 50 students, but at the same time a research, test and demonstration environment for e.g. energy efficiency, resource optimization, electricity generation, laundry habits, cooking possibilities and so on.

Figure 3. The HSB Living Lab as seen from Johanneberg Science Park.

In IRIS, HSB Living Lab contribute with a demonstration and evaluation of so called BIPV, Building Integrated Photo Voltaics. This means solar panels for renewable electricity generation that can be mounted on houses instead of other construction material in new built houses or in connection to renovation of the façade or roof exchange. This demonstrator focuses on the situation at the end of the service life of the façade and roof materials.

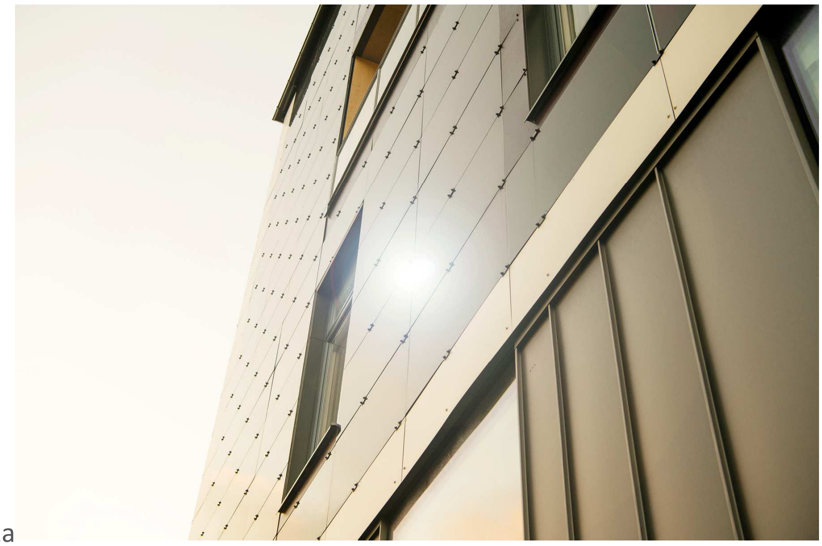
za 

Figure 4. The HSB Living Lab after installation of Building Integrated PhotoVoltaics.

2.3 Integrated Solutions in TT#1

All demonstrators 1-7 in this deliverable contribute to Integrated solution IS-1.1: Positive Energy Buildings.

- Demonstrator 1 contributes to Integrated solution IS-2.3: Utilizing 2nd life batteries for smart large-scale storage schemes.
- Demonstrators 3, 4 and 5 contribute to Integrated Solutions IS-2.2: Smart multi-sourced low temperature district heating with innovative storage solutions.
- Demonstrator 6 contributes to Integrated solution IS-2.1: Flexible electricity grid networks.
- Demonstrator 7 contributes to Integrated solution IS-1.2: Near zero energy retrofit district.

2.4 Integration of Demonstrators

Within this transition track, demonstrators 1-6 are closely connected.

- The PVs in demonstrator 1 are powering, among other things, the heat pumps that are seen in demonstrator 2, 3 and 4.
- The cooling produced in the boreholes under demonstrator 3 is transported to a neighbouring office building under demonstrator 5, with the added benefit of improving the efficiency of the heat pumps that are seen in demonstrator 2, 3 and 4, and partly stored in the boreholes under demonstrator 4.
- The thermal energy storages in demonstrator 4 aim to increase the efficiency and extend the service life of the heat pumps that are seen in demonstrator 2 and 3.
- The energy management system in demonstrator 6 manage the components in demonstrators 1-5.

2.5 Deviations according to the Grant Agreement

In brf Viva, the size of the PV system has been increased from an initially planned 140 kWp to an installed power of 170 kWp. This change occurred while revisiting the overall energy balance for Viva and noticing that an extra addition of locally produced electricity was necessary to safely be able to predict a positive balance. Therefore, not only the roofs of the three high buildings in Viva were clad with PVs but also the southernmost low building, as can be seen in Figure 7. At the same time, the cost of PVs has fallen quickly and thereby enabling an economically viable installation to occur on a less ideal position, as the roof of the lower building is.

The seasonal energy trading of measures 3 and 5 have not been able to launch due to a lack of agreement with the owner of CTP over how to bear increased costs that have risen since initial design and calculations. Until it can launch, it will not be possible to demonstrate energy storage in the bore holes under measure 4. The storage in the building structure is operating in the sense that it inevitably contributes to the thermal inertia of the building, but getting it included in the heating management system to provide thermal comfort is still under investigation.

There are no deviations in HSBLL.

3 Baseline, Drivers and Barriers

With baseline, we understand the situation before any intervention has been made. The overall baseline, when considering the effect of the projects in their entirety, is seen as an imagined building that is quite ordinary and only adheres to building codes. However, when considering the effect of the individual solutions, the baseline is a credible and functional version of the energy system that would work without the solution in question.

3.1 Baseline for Viva

Riksbyggen's Brf Viva (Fig.1) is built on land that is previously undeveloped (Fig. 5), 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. It would have either district heating or downhole heat pumps, not both. It would have accumulator tanks and its structure would influence the thermal inertia of the building.

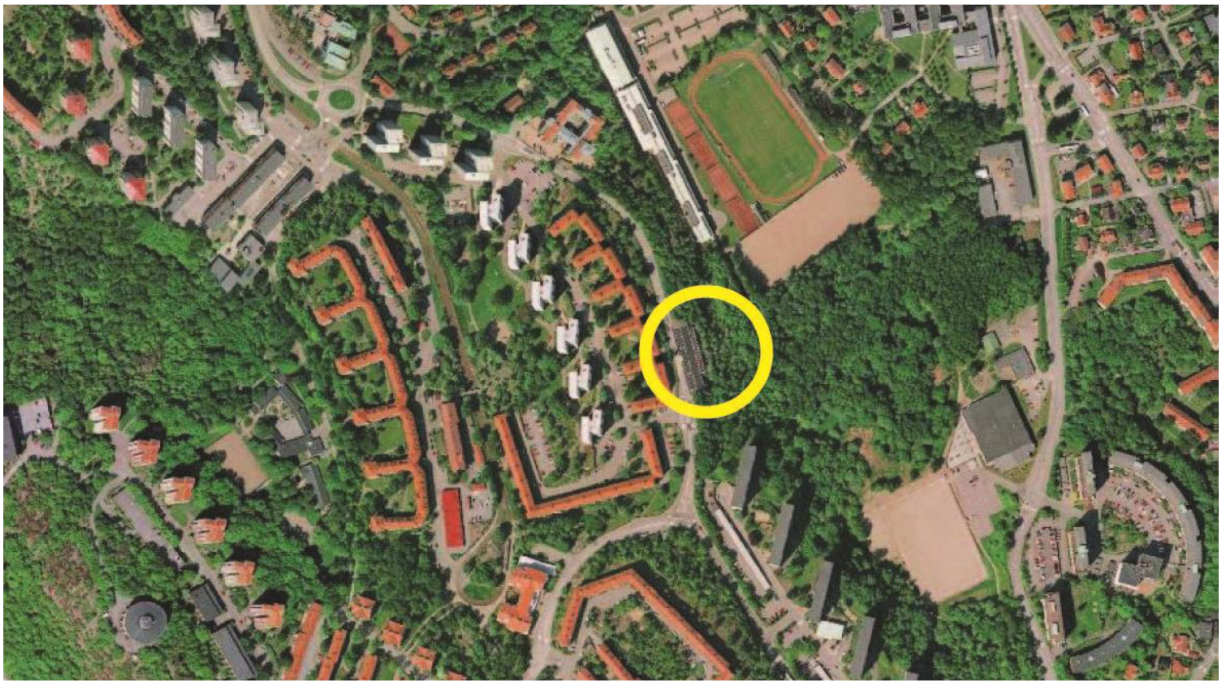
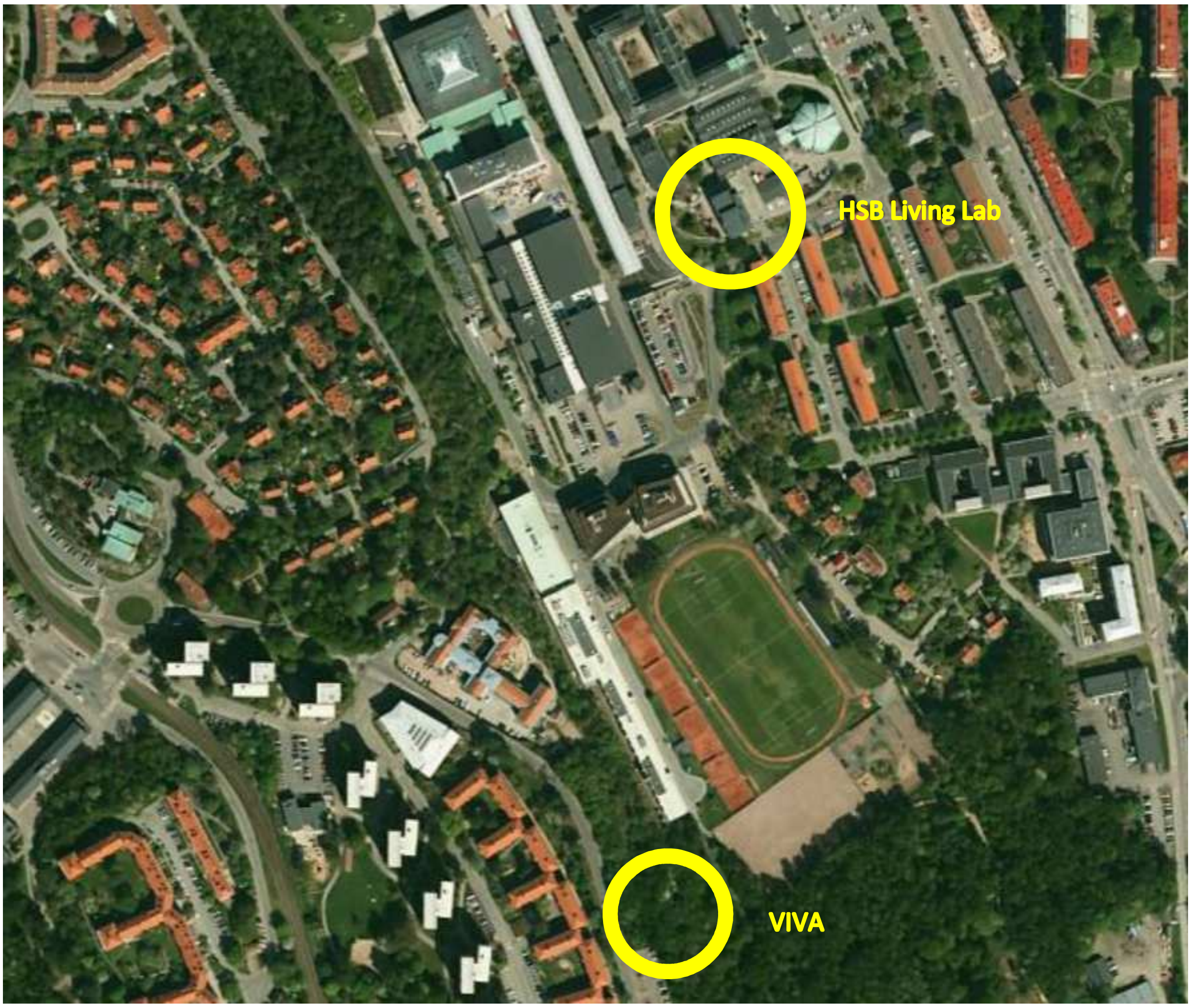


Figure 5 The site of Viva prior to development

3.2 Baseline for HSB Living Lab

There are two relevant baselines for the demonstration of Building Integrated Photo Voltaics (BIPV) for solar electricity generation:

- Solar cells are placed as an extra layer on the façade and on the roof, in connection to renovation of the same. An economic comparison is therefore made with solar PV put on top of a standard construction element. This comparison and evaluation constitute the demonstrator in IRIS.
- No solar cells are included in the energy system. This enables an evaluation into the increased level of energy self-supply, energy savings, etc.



3.3 Drivers and Barriers

3.3.1 *Political*

Barriers

Differing interests, from the actors that together form an energy system (housing association, energy utility company, property owner, EU-sponsored project(s) etc.) have differing goals for the optimization of the Energy Monitoring System.

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.

3.3.2 *Economic*

Barriers

Large investment costs and long payback times for batteries and other storage options may act as a barrier for market introduction.

Drivers

Higher efficiency, lower consumption and own production will lower the energy costs for property owners and residents.

3.3.3 *Sociological*

Barriers

There could be challenges in the operating phase for the energy management system, if the ownership of the building in question is of another actor. The level of knowledge in energy related questions among the residents in the house might also impose challenges, if the residents also own the apartments.

Renovation of old buildings with BIPV would at present mean a change in the visual appearance of the building. This can make it difficult to gain acceptance from both the residents and the municipality's architects who provide building permits.

3.3.4 *Technological*

Barriers

The high speed of technology development implies barriers such as mistrust in the business towards unproven technology and lack of a proper standardisation.

Security/ reliability/ serviceability of the whole system remains to be proven.

Drivers

The current technology development in energy efficiency and renewable electricity generation and the possibility to connect all components into a single system, enables the implementation and realization of the demonstrators in this transition track.

3.3.5 *Legal*

Drivers

Riksbyggen is technically not a company but an “economic association”. This relieves them from the quarterly economic system and the stress it implies and gives them the possibility to act on a more long-term basis.

Barriers

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

The pipes with cooling water that connect the two buildings are drawn/lain/positioned on ground that is owned by the municipality. Since this is a new way of conducting energy exchanges, there is no precursor for how to make legal agreements for how the use of the land can be conducted. Specifically, these types of leases for public land is hereto always written with a three-month cancellation clause, which would make an investment with of 20 years of service life considerably riskier.

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)

3.3.6 *Environmental*

Drivers

The strong commitment from all levels in Riksbyggen in the work with sustainability in Positive Footprint Housing, that led to Brf Viva, has been a strong driving force.

The strong and outspoken will to work with sustainable development, among all actors involved, is a strong driving force in the daily work.

Barriers

The Swedish electricity mix is mainly based on hydro power, nuclear power and biofuel and is therefore nearly CO_2-neutral. Better connections with the north-European electricity network has given Sweden a better redundancy in the electricity grid and a possibility to export domestically generated electricity, but also the possibility to rely more on electricity from our neighboring countries, not necessarily carbon neutral. Therefore, there is a discussion whether electricity driven heat pumps are an environmentally good alternative for heating, when district heating also is available.

4 Organisation of work

4.1 Organization of work – Viva

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.

4.2 Organization of work –HSB Living Lab:

The organization consisted of:

Project group

- Zack Norwood, Researcher at University of Gothenburg
- Dan-Eric Archer, project manager and energy consultant at Emulsionen
- Shea Hagy, Researcher at Chalmers University of Technology
- Filippa Sandgren, assigned development specialist at Göteborg Energi.

Contracting client

- Amanda Sandquist and David Albinsson, property managers at HSB
- Rickard Malm, Research and development manager at HSB

Contractor

- Elin Elmehag and Stefan Jennefalk, suppliers of BIPV and associated equipment at Merasol

5 Demonstration of at least 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV

5.1 Specifications

This measure is exploring the re-usefulness of vehicle batteries in stationary applications, together with solar PVs.

Electricity is generated on the roof of four of the six buildings in Viva; the three high ones and the southmost low one. The electricity is either used directly or stored in the batteries to be used later. This way, the building in which the batteries are installed is then able to store excess electricity that was generated by the PVs. This makes it possible for more of the electricity consumption of the whole building to be covered by locally produced renewable electricity. For situations when the electricity in the grid has particularly low price or low carbon intensity, it could also be desirable to charge the batteries from the grid. That way, the energy storage can contribute to an increased flexibility in the surrounding grid and further the development of the smart power grids of the future.

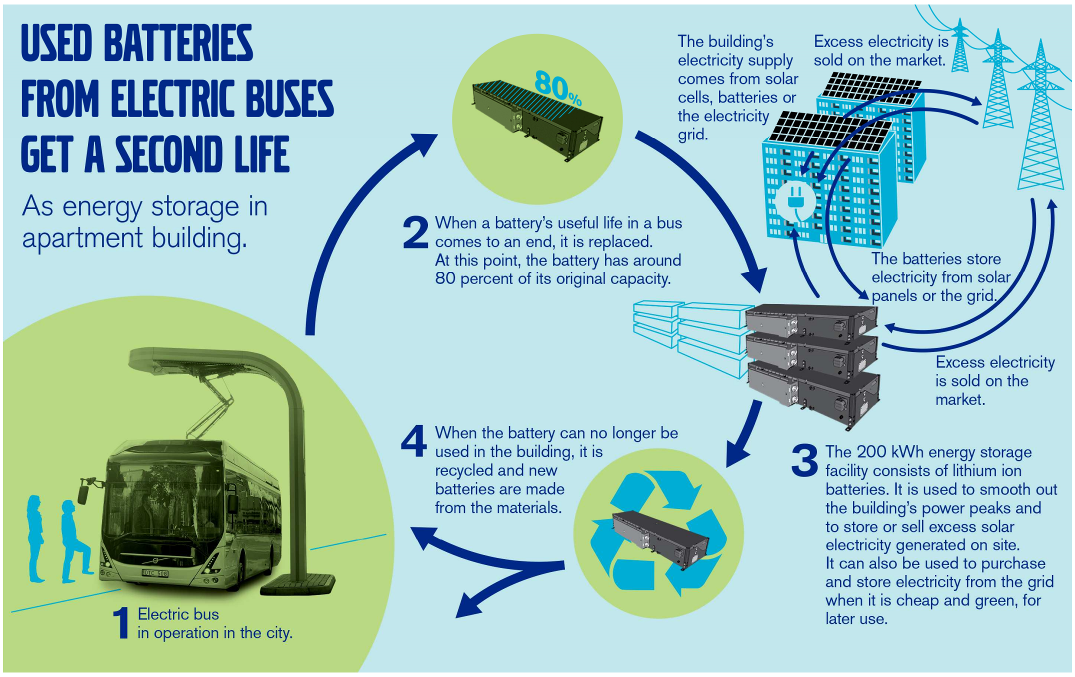


Figure 6. The circularity of the batteries

The batteries are taken from their mobile service in busses, when roughly 80% of original capacity remains, and given a second life in a stationary application. This leads to an improved efficiency in the use of resources as well as a reduced environmental impact.

The purpose of this measure is to:

- Generate a better understanding of how individual buildings and larger energy systems can coexist.
- Contribute to a better resource efficiency when using batteries in buildings and vehicles.
- Improve the possibilities for producing renewable electricity in Sweden.
- Dissipate knowledge of sustainable living and the energy systems of the future.

5.1.1 *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.

The batteries are constituted of a large amount of smaller battery cells which are integrated in modules, and the modules are connected to larger packs including functions like cooling, intelligent controls and encapsulation. The battery case is built by a protective steel shell and includes electronics, cables and cooling pads. These 14 batteries are installed in a separate room and joined to form a functioning energy storage of roughly 200 kWh. Each battery is about two meters long and weighs 350 kg.

The building geometry has been adapted to improve the conditions for PV electricity production. The three high buildings are oriented along the east-west-axis, and all have their roofs slanting toward south at a suitable angle. Also, the entire roof surface has been designed to be uninterrupted by openings for ventilation, power, bushings, access hatches or such. This way, more of the roof surface is available for PV panels and a higher capacity can be installed.

At the time of the application for the IRIS-project, an effect of 140 kWp was expected to be installed. The final installation was instead 290 Wp * 589 panels = 170 kWp or 964 m^2 because also one of the low buildings got its roof covered with PVs. In total, the PV system is expected to produce around 160 MWh annually, on a year with normal irradiation. This covers about half of the electricity demand for the building itself, i.e. disregarding the demand inside the households.

Figure 7 Brf Viva with its PV clad roofs

5.1.2 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.

Maximum Power Point Tracker (MPPT) software is deployed to in the PV circuits to minimize voltage losses and thereby maximize production.

5.2 Societal, user and business aspects:

5.2.1 *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 (very secure and well-priced) 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.

Figure 8 Inside the battery storage.

5.2.2 *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. N.B. that this is considering the planned amount of PV capacity: 140 kWp. However, the installed capacity PV has risen to 170,8 kWp, since also a fourth roof has been clad with panels. This might still increase the portion of sold electricity.

For scale, the fully charged battery storage in Viva could charge 4,5 electric cars of 40 kWh, 30 electric bikes of 0,5 kWh and run 5 washing machines of 1 kWh each.

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. Therefore, Volvo will use the same demonstrator in a parallel research project to get LCA and LCC data to construct and update their relevant business models accordingly.

5.2.3 *Governance*

During the project period of IRIS, Riksbyggen will hold the contract with the association for maintenance and service of the facilities in Viva. The association is one of three contractual parties, together with Riksbyggen, Göteborg Energi and Volvo Buses, that have agreed to “enable research” on and in the energy system in Viva.

The batteries were developed for buses by Volvo Buses and are still supplied and owned by Volvo.

5.3 Impact Assessment

5.3.1 *Expected impact*

With a successful implementation of this demonstrator, we expect to see:

- Increased degree of self-sufficiency, together with
- 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 CO_2 emissions.

5.3.2 *KPIs*

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

Table 2. Summary-list of KPIs and related parameters for Measure 1

KPI	Parameter(s)	Baseline	Target
Carbon dioxide Emission Reduction	Hourly load curve from the apartments [Wh],	Baseline is the load curve from the apartments, unassisted by either batteries or PVs, times the carbon intensity with hourly resolution on the imported electricity.	15-20%, or 10 metric tonnes.
	Hourly electricity production from PVs [Wh]		
	Hourly electricity delivered from the grid [Wh]		
	Hourly carbon intensity of the grid electricity [g CO_2-e/Wh]		
Degree of energy self-supply by RES	Monthly electricity production from PVs [Wh]	Zero percent self-sufficiency.	Brf Viva's degree of self-supply for **electrical** energy is expected to vary between 10% and 60%.
	Monthly electricity delivered from the grid [Wh]		
Energy savings	Hourly load curve from the apartments [Wh],	The electricity demand of Viva.	25-40% annual electric energy savings.
	Hourly electricity production from PVs [Wh]		
	Hourly electricity delivered from the grid [Wh]		

5.3.3 *Monitoring plan*

The monitoring 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. They are also part in IRIS and another cooperative research project dealing specifically with advanced energy management.

5.4 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 constructor in charge of that particular piece of the building has to keep working to deliver the promised results.

Table 3 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	
		K21 - Solkompaniet	Secondary contract	

			for PV system	
		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, including roof, is prepared for installation of PVs and batteries	
	Installation & connection of PVs	PV installation subcontractor, Solkompaniet		
	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 • PVs • Batteries	

5.5 Implementation plan

5.5.1 *Planning of activities*

Two years after start of service of the electricity storage, we will have gathered enough data and experience 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.

5.5.2 *Planning of costs and (equipment) investments*

There are currently no planned purchases for this measure.

5.5.3 *Risk management*

Table 4 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-	Keep the batteries cooled below 80 degrees Celsius, and	Low	Low	The alarms in the room would be able to detect

threatening gases from the batteries	no gases will be emitted.	this.

5.5.4 *Progress achieved up to M24*

The batteries and all accompanying systems for control, management and safety are installed and running. All PVs have been installed.

5.6 Conclusion

The batteries were perhaps installed a bit too early, since no PVs were in place at the time. Also, the DUC that runs internal communication between the components could not be installed until late in phase 3, i.e. around May 2019, which meant that the whole package was completed some 10 months after the batteries were delivered. It would have been preferable to shorten that time span.

The installation of the hardware in the battery room was organized in a separate contract, with a separate contractor, from the rest of the construction. This meant some miscommunication and lack of cooperation between the different groups of workers, resulting among other in that the power supply to the battery room got delayed.

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.

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

6.1 Specifications

This measure introduces heating of Viva by heat pumps drawing geothermal energy from deep boreholes.

The temperature in the boreholes stays relatively constant around the average annual temperature which is eight degrees in Gothenburg. Heat pumps are used to raise the temperature of the water coming up from the holes to 45 degrees. This is then led from the main energy central to the three sub-centrals, one for each high-low pair of buildings in Viva, where a heat exchanger brings the heat into the radiator system. Each sub-central also brings the temperatures up to 60 degrees for hot tap water. The geo energy system is designed and sized to be able to provide hot water during also the coldest days of the year without direct use of electric heaters.

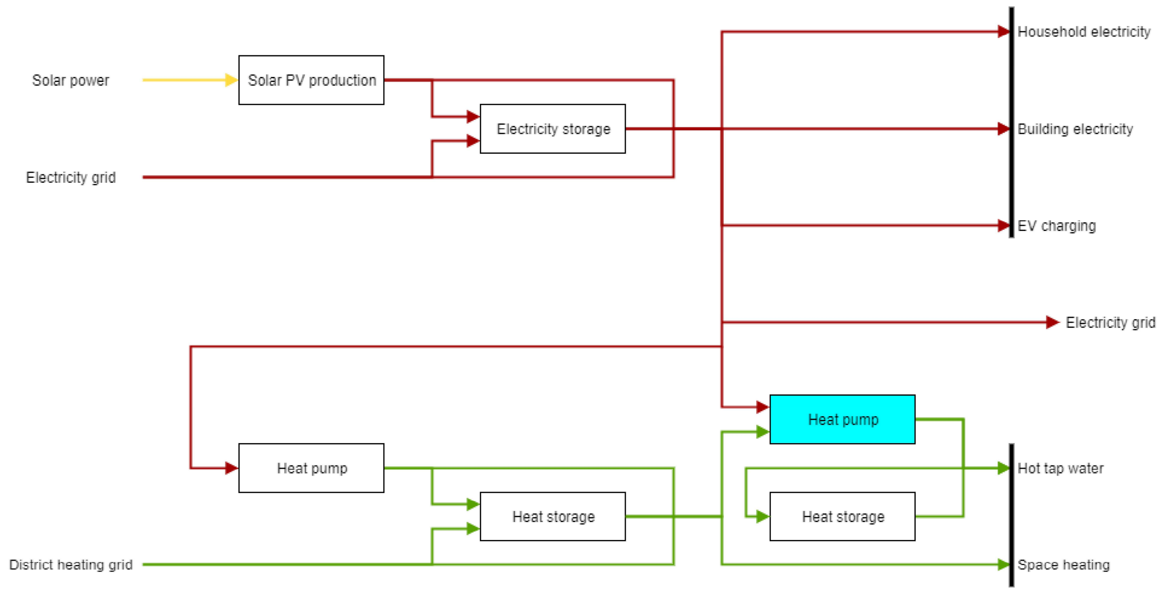


Figure 9 The overall schematic of the energy system in Viva. Note the Heat pump, marked in teal, which is where the heat from the geothermal energy enters the system.

6.1.1 *Hardware*

- 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.
- There are 19 boreholes reaching some 230 meters down into the bedrock.

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.

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.

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.

6.2.2 *Business model*

Despite relatively high investment costs, this measure is economically viable in a long-term perspective. Particularly when the building produces its own renewable electricity. For standard applications in Sweden, the payback time for these kinds of systems is 5-7 years.

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.

6.3 Impact Assessment

6.3.1 *Expected impact*

With a successful implementation of this demonstrator, we expect to see a heating system with steady service, providing high comfort with a low amount of purchased energy.

6.3.2 *KPIs*

The following KPI:s 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 2

KPI	Parameter(s)	Baseline	Target
Degree of energy self-supply by RES	Monthly produced thermal energy in Viva [Wh]	Zero self supply.	Varying between 0% and 100% for **thermal** energy.[1]
	Montlhy used thermal energy [Wh]		
Carbon dioxide Emission Reduction	Hourly thermal load curve from the apartments [Wh],	0% reduction	90% reduction.
	Hourly thermal energy production in Viva [Wh]		
	Hourly thermal energy delivered from the grid [Wh]		
	Hourly carbon intensity of the DH grid [g CO_2-e/Wh]		
CO_2 reduction cost efficiency	Yearly carbon dioxide Emission Reduction [tonnes/year]	N/A	400 €/tonne CO2e*y
	Investment cost [€]		
	Service life [years]		
	Running costs [€/year]		

6.3.3 *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. They are also part in IRIS and another cooperative research project dealing specifically with advanced energy management.

6.4 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 constructor in charge of that particular piece of the building has to keep working to deliver the promised results.

[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.

Table 6 Commissioning plan for Measure 2

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,	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	
		K21 - other subcontractors, Riksbyggen vetoes	Secondary contracts	
4 Realization	Oversee and coordinate work	Coordinating contractor k21	Build	
	Installation & connection of bore holes & heat pumps	Bore hole installation subcontractor		
5 Testing	Systems testing	Installation coordinator	• Control of how well technical systems fulfils specifications in drawings • Control of that the different systems	CE

			communicate correctly	
	Technical inspection	Inspectors for areas, respectively; e.g. piping, electrical, construction	When deviations occur, k21 conducts the corresponding sub-contractor to correct the work.	
	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	Accept responsibility over maintenance of energy system	

6.5 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.

6.5.1 *Planning of activities*

No more activities are planned.

6.5.2 *Planning of costs and (equipment) investments*

No more costs are planned.

6.5.3 *Risk management*

Heat pumps are custom built for this application. They might display unexpected behavior.

Table 7 Risks and mitigation activities for Measure 2

Risk	Mitigation Activity	Probability	Impact	Comment
Heat pumps malfunction	Automatic and manual oversight to assure intended function.	Low	Medium	Since the heat pumps are custom built, the design has had less testing than off-the-shelf products.
Bore holes get gradually cooler and less	Place them further apart. Recharge them with excess heat during summertime	Low	Low	Placements are fixed. The recharge is subject to launch of Measures 3

effective at heating				and 5.
The association loses trust in the project and withdraws	Provide continuous, clear and transparent communication. Explain what is being done and why.	Low	High	

6.5.4 *Progress achieved up to M24*

All is done. The system has started operating in phases as the buildings have been constructed and are now fully operational and heating the houses.

6.6 Conclusion

The heat pumps have been custom built but are so far operating as planned. Some minor fixes of the programming have been made.

The power supply was designed too small in the construction drawings, which was dealt with and corrected.

During the first service year, the system will run mainly, if not solely, on these heat pumps in an effort to optimize purchased energy. This is done to assure the Swedish building certification label of “Environmental Building Gold”. After this has been attained, the system will also consider cost, carbon intensity and peak shaving in the energy management system.

7 Demonstration of cooling from geo energy without chillers

Firstly, this measure has not been possible to launch at this point.

This demonstrator is a joint effort with another property owner, called CFAB, who is not a part of IRIS. Their participation is an absolute requirement for the realization of the demonstrator, but their incentives and motivations are different from those of Riksbyggen. Also, from the first stage of planning, when it was decided to try to make this demonstrator a reality, the necessary level of investment has more than doubled, at the same time as personnel changes within CFAB has changed their attitude towards the project. This means that additional and unplanned activities are needed to secure funding to reach an agreement with CFAB. This additional fundraising attempt has been ongoing the last 18 months, so far without success.

7.1 Specifications

This measure is a system which circulates return water from the comfort cooling system of the office building CTP to the heating system in Viva, thereby transferring cooling to CTP.

The boreholes are part of Vivas heating system. Cold water is then transferred from the boreholes to the office building where it is used to provide a more comfortable and cooler indoor environment. Without this measure, Viva has a heating demand and CTP has a cooling demand, and both purchase electricity to produce heating and cooling, respectively. With this measure, the opposing demands would be short-circuited and the amount of purchased electricity reduced. Additionally, with the inclusion of this measure in the energy balance of Viva, it is expected to make it a positive energy building.

7.1.1 *Hardware*

Table 8 Hardware planned to enable geothermal cooling

Article	Description
Insulated water pipes	129*2,0 mm steel pipes, insulated by a 13 mm foam tubing.
Heat exchanger 120 kW	
Meters, filters, vents,	
Controlling and management system	

7.1.2 *Software*

The control will probably be quite simple. If the need for cooling in CTP is big enough, a circulation pump will shift energy between the buildings.

7.1.3 *Procurement of equipment and/or services*

CFAB will do the purchasing.

7.2 Societal, user and business aspects:

7.2.1 *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.

Also, the housing association will be paid by CFAB for their cooling, earning the association an estimated 3 000 € annually.

7.2.2 *Business model*

This kind of bilateral energy exchange, between buildings with heating and cooling demand, respectively, has a relatively high potential for replication. There is an increasing number of housing buildings with heat pump systems located near office buildings.

When this demonstrator is fully implemented, is will also be possible to calculate the economic viability for the more likely replication scenario where the energy is exchanged between buildings that are physically closer to each other. This would lower the investment cost noticeably, since even the tubes that transport the water cost 150 € /m. This way, a more general profitability calculation could be presented.

7.2.3 *Governance*

During the project period of IRIS, Riksbyggen will hold the contract of maintenance and service of the facilities in Viva. The real estate company ChalmersFastigheter AB (CFAB) owns CTP and is therefore an integral part of this demonstrator.

7.3 Impact Assessment

7.3.1 *Expected impact*

With a successful implementation of this demonstrator, we expect to see:

- A cooling system providing high comfort to a low energy cost.
- Proof of the usefulness of bilateral DH-style connections of this kind.
- Greatly improved energy balance for both participating buildings.

7.3.2 *KPIs*

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

Table 9. Summary-list of KPIs and related parameters for Measure 3

KPI	Parameter(s)	Baseline	Target
Degree of energy self-supply by RES	Current levels of cooling used in CTP. [Wh]	The current annual cooling demand of CTP is entirely provided by purchased energy, thus baseline is 0%.	A substantial amount, hopefully up to 80%
	Supplied amount of cooling by Viva. [Wh]		
Carbon dioxide Emission Reduction	Current levels of cooling used in CTP. [Wh]	The CO2-emissions to fulfil the current annual cooling demand of CTP, before this measure is deployed.	A substantial amount, hopefully **up to 80 %** of the annual CO2-emissions associated with providing the cooling needed in CTP can be reduced by the cooling suppplied by Viva.
	Associated energy usage [Wh]		
	Supplied amount of cooling by Viva. [Wh]		
	Hourly carbon intensity of the electricity grid [g CO_2-e/Wh]		
CO_2 reduction cost efficiency	Yearly carbon dioxide Emission Reduction [tonnes/year]	N/A	59 000€/tonne*y
	Investment cost [€]		
	Service life [years]		
	Running costs [€/year]		

7.3.3 *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. They are also part in IRIS and another cooperative research project dealing specifically with advanced energy management.

Specifically, the efficiency (COP) of the heat pumps will be measured continuously, as will the temperature in the bore holes. Based on these measurements, the improvement in COP due to recharge can be calculated. In CTP, the received cooling from Viva will be measured continuously. Based on those, the yearly savings in service time and used electricity of the cooling machines in CTP can be calculated.

7.4 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 constructor in charge of that particular piece of the building has to keep working to deliver the promised results.

For this measure, the process has stalled in the contracting phase.

Table 10 Commissioning plan for Measure 3

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,	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	Technical consultant	Energy balance	

	energy system	Bengt Dahlgren AB	planning	
3 Contracting	Acquire coordinating contractor	Riksbyggen - k21	Primary contract	
		K21 - other subcontractors, Riksbyggen vetoes	Secondary contracts	
		Riksbyggen – CFAB	Primary contract to finalize financing	
		CFAB – Housing association Viva	Primary contract for running energy trade	
4 Realization	Oversee and coordinate work	Coordinating contractor k21	Build	
	Installation & connection of cooling system	Piping subcontractor		
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, electrical, construction	When deviations occur, k21 conducts the corresponding sub-contractor to correct the work.	
	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	Accept responsibility over maintenance of energy system	
	Start of trade	CFAB, Association, Riksbyggen		

7.5 Implementation plan

7.5.1 *Planning of activities*

The single ongoing activity is securing funding to buy and install the hardware in CTP so that the system can be completed, and the demonstrator can be launched.

7.5.2 *Planning of costs and (equipment) investments*

Further equipment investments are planned, in the CTP.

Table 11 Planned investments in CTP

Article	Amount	Estimated cost (€)
Insulated water pipes	300 m	53 000
Heat exchanger 120 kW	1	5 000
Glycol as heat carrier		1 000
Meters, filters, vents,	Assorted	14 000
Controlling and management system		10 000
Labor	550 hours	27 000
Bought services		21 000
		Total: 145 000

7.5.3 *Risk management*

As signaled in the Local risk assessment in D7.2, the full financing for the measure is not yet covered. The same applies to measure 5 under Chapter 10 “Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block”, which is a demonstration that entirely depend on the same hardware. This is considered of medium to high probability and high impact.

Table 12 Risks and mitigation activities for Measure 3 and 5

Risk	Mitigation Activity	Probability	Impact	Comment
Insufficient funding to launch	Search for possible investors, apply for innovation funding, apply for climate mitigation funding.	Medium – high	High	See above.
Association loses interest	Give the association a high enough price for their cooling.	Low	High	
Municipality discontinues	Negotiate a long-term lease. Articulate the benefits on a city-scale for these solutions.	Low	High	

lease on land for the tubes	Engage national energy agency and municipal utility company in the project

7.5.4 Progress achieved up to M24

All installations in Viva are complete. Also, the pluming and culvert connecting the two buildings is finished and paid for by Riksbyggen.

7.6 Conclusion

Since this demonstrator is not installed yet, it is not possible to draw any conclusions from its launch. However, it is possible to acknowledge that is would probably have been helpful having CFAB being a part of IRIS since that would have given them an external delivery demand to relate to.

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

8.1 Specifications

This measure incorporates a couple of different thermal energy storages into the overall energy system of Viva.

8.1.1 *Hardware*

There are accumulator tanks in four places in Viva. In the main energy central, that services the entire group of buildings, there are 2 tanks to relieve the heat exchangers from turning on and off too often. Each of these tanks hold 2000 liters which brings a storage capacity of 160 kWh, working with a temperature difference of 30 degrees. Additionally, there are 9 tanks in each of the 3 sub centrals, that store hot tap water. Each of these tanks hold 500 liters which brings a storage capacity of 810 kWh, working with a temperature difference of 52 degrees.

The total thermal energy storage in the accumulator tanks is 970 kWh.

If it can be considered hardware in this respect, the thermal inertia of the concrete building structure effectively acts as a short-term passively controlled energy storage.

8.1.2 *Software*

Investigations whether to control the heating system with respect to the thermal inertia of the structure are currently underway.

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.

8.2.2 *Business model*

The desire to avoid the highest consumption peaks exists also in the district heating system. When these peaks occur, the support power facilities are brought online, and they are the niches in system when fossil fuels are still being burnt in Gothenburg. Therefore, the ability to utilize stored thermal energy and shift energy usage in Viva is of great value, since the carbon intensity in the DH grid varies hour-by hour. Therefore, hourly prices on district heating can be anticipated in the future.

8.2.3 *Governance*

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

8.3 Impact Assessment

8.3.1 *Expected impact*

With a successful implementation of this demonstrator, we expect to see:

- Increased thermal storage capacity, providing
- Increased ability of flexibility, resulting in
- Reduced peak loads and CO_2 emissions

8.3.2 KPIs

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

Table 13. Summary-list of KPIs and related parameters for Measure 4

KPI	Parameter(s)	Baseline	Target
Storage capacity installed	Volume of accumulator tanks [m^3]	The baseline is 0 kWh.	970 kWh in tanks. N/A for boreholes and structure.
	Temperature interval of accumulator tanks [K]		
	Conditioned floor area of Viva [m^2]		
	Storage capacity in the structure [Wh]		
Peak load reduction	Space heating demand [Wh]	The baseline is the consumed heat in the building.	The thermal peak load will be reduced.
	Hot tap water demand [Wh]		
	Heat produced by heat pumps [Wh]		
	Purchased DH [W]		
Carbon dioxide Emission Reduction	The thermal demand curve from the apartments [Wh]	The thermal demand curve from the apartments, including hot tap water, multiplied by carbon intensity values. Both with hourly resolution.	We estimate, very roughly though enthusiastically, that the emission reductions should be around 3 tonnes annually.
	including hot tap water demand curve from the apartments [Wh]		
	Hourly carbon intensity of the DH grid [g CO_2-e/Wh]		
CO_2 reduction cost efficiency	Yearly carbon dioxide Emission Reduction [tonnes/year]		4 000 €/tonne*y
	Investment cost [€]		
	Service life [years]		
	Running costs [€/year]		

8.3.3 Monitoring plan

Monitoring 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. 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 constructor in charge of that particular piece of the building has to keep working to deliver the promised results.

Table 14 Commissioning plan for Measure 4

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	
		K21 - Solkompaniet	Secondary contract for PV system	
		Riksbyggen – Gothenburg Energy	Secondary contract for energy trading with city grid	
		K21 - other subcontractors, Riksbyggen vetoes	Secondary contracts	
4 Realization	Oversee and	Coordinating contractor	Make sure the	

	coordinate work	k21	building, including energy centrals are prepared for installation of tanks	
	Install tanks	Sub-contractor		
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.	
	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	Accept responsibility over maintenance of energy system	

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 accumulator tank system running have been made.

8.5.1 *Planning of activities*

The storage in the building structure is operating in the sense that it inevitably contributes, but getting it included in the heating system to provide thermal comfort is still under investigation.

Once the demonstrators described chapters 7 and 9 in in this report were to be completed, long-term thermal energy storage in the boreholes comes into question. Activities to launch them are described mainly in chapter 7.

8.5.2 *Planning of costs and (equipment) investments*

There are currently no planned purchases for this measure.

8.5.3 Risk management

Table 15 Risks and mitigation activities for Measure 4

Risk	Mitigation Activity	Probability	Impact	Comment
Storage in bore holes impossible due to lack of seasonal energy trading.	See table 12 Risks and mitigation activities for Measure 3 and 5.	Medium – high	Medium	
Storage in bore holes ineffectual due to too large spacing.	N/A	Medium	Medium	The spacing is set and cannot be influenced.
Storage in thermal inertia impossible to assess	Look for experts who can help us.	Medium	Low	

8.5.4 Progress achieved up to M24

The storage in the accumulator tanks is up and running. The storage in the bore holes has not started. The storage in the building structure is operating in the sense that it inevitably contributes, but getting it included in the heating system to provide thermal comfort is still under investigations.

8.6 Conclusion

The accumulator tanks are operating as expected. It is hard to assess the contribution of the thermal inertia. The contribution of the storage in the bore holes will be able to be assessed after their start of service.

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

9.1 Specifications

This measure is a system which trades heated cooling water from the office building CTP, with cooled water from the boreholes in Viva.

See chapter 7 for further descriptions.

9.2 Impact Assessment

9.2.1 *Expected impact*

With a successful implementation of this demonstrator, we expect to see:

- A cooling system providing high comfort to a low energy cost.
- Proof of the usefulness of bilateral DH-style connections of this kind.
- Greatly improved energy balance for both participating buildings.

9.2.2 *KPIs*

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

Table 16. Summary-list of KPIs and related parameters for Measure 5

KPI	Parameter(s)	Baseline	Target
Peak load reduction	Purchased power to CTP [W] Purchased power to Viva [W] Annual peak power in CTP [W] Annual peak power in Viva [W] First Annual peak power in Viva [W]	Current peak power to meet the demand for **cooling in CTP**, and first peak power to meet the demand for **heating in Viva.**	With a successful deployment of the solution, the peak power load reduction could be 25% in CTP and 0% in Brf Viva.
Reduced energy cost for	Monthly costs in CTP [€]	For the office building CTP: the current annual	Chalmersfastigheter saved 70% annually on

consumers	Monthly costs in Viva [€]	cost for cooling. For the apartment buildings Viva: 0.	cooling costs from the energy trading. Viva gains 30 000 SEK annually from running the energy trading.
Carbon dioxide emission reduction	Hourly purchased electricity curves in CTP [Wh] Hourly purchased electricity curves in Viva [Wh] Hourly purchased heating curves in Viva [Wh] Monthly energy use during the first service year in Brf Viva before the seasonal energy trading is deployed. [Wh] Hourly carbon intensity of the DH grid [g CO_2-e/Wh] Hourly carbon intensity of the electricity grid [g CO_2-e/Wh]	The CO2-emissions to fulfil the current annual cooling demand of CTP and heating demand of Viva, before this measure is deployed.	With a successful deployment of the solution the CO2 emissions reduction could be: • 50% (0,46 t) in CTP • 10% (0,35 t) in Viva.
CO_2 emission reduction cost efficiency	Yearly carbon dioxide Emission Reduction [tonnes/year] Investment cost [€] Service life [years] Running costs [€/year]	N/A	33 k€/tonnes*y
Energy savings	Monthly purchased electricity in CTP [Wh] Monthly purchased electricity in Viva [Wh] Monthly purchased heating in Viva [Wh] Monthly energy use during the first service year in Brf Viva before the seasonal energy trading is deployed. [Wh]	Current monthly electric energy use to meet the demand for **cooling in CTP**, and monthly energy during the first service year use to meet the demand for **heating in Viva**.	With a successful deployment of the solution: • the thermal energy savings should be 0% in CTP • the thermal energy savings should be near 0% in Viva. • the electric energy savings could be 50% in CTP • the electric energy savings could be 10% in Viva

9.2.3 *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. They are also part in IRIS and another cooperative research project dealing specifically with advanced energy management.

9.3 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.

Table 17 Commissioning plan for Measure 2

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,	List of innovations to be included and demonstrated in brf Viva	N/A
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		Riksbyggen – CFAB	Primary contract to finalize financing	
		CFAB – Housing association Viva	Primary contract for running energy trade	
4 Realization	Oversee and coordinate work	Coordinating contractor k21	Build	
5 Testing	Systems testing	Installation coordinator	• Control of how well technical systems fulfils specifications in drawings • Control of that	CE

			the different systems communicate correctly	
	Test of function	Representatives from all companies involved in realization of measure	Testing of all systems, sub-systems and components.	
6 Completion	Start of trade	CFAB	Initiate and run energy trading and its associated costs.	

9.4 Implementation plan

Identical to demonstrator 3 in chapter 8 above.

9.4.1 *Progress achieved up to M24*

All installations in Viva are complete. Also, the pluming and culvert connecting the two buildings is finished and paid for by Riksbyggen.

9.5 Conclusion

Since this demonstrator is not installed yet, it is not possible to draw any conclusions from its launch. However, it is possible to acknowledge that is would probably have been helpful having CFAB being a part of IRIS since that would have given them an external delivery demand to relate to.

10 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

10.1 Specifications

This demonstrator introduces an intelligent control system which will be installed and manage the power flows within the energy system in Viva.

The measure aims to provide a better understanding of how the energy system can be optimized from a residential housing perspective and as part of the larger energy systems in Gothenburg. The battery storage will be used to store locally produced solar energy, and this energy can be used within the residential block, for charging electrical vehicles and in connection to the external power grid. During the ongoing parallel research project, the electricity storage is one part of the energy system that also includes the photovoltaic cells, the electricity network connection, boreholes, heat pumps, accumulator tanks and district heating. The optimization and control of the whole system aim to minimize the overall energy costs and environmental impact as well as improve energy efficiency.

10.1.1 *Hardware*

This demonstrator controls the rest of the energy system in Viva and does not have its own dedicated hardware, except for one router that is necessary to make the communication work between the local and remote systems through a VPN tunnel, i.e. the system runs on existing hardware.

10.1.2 *Software*

A control algorithm will use available data about the energy system, as well as forecasts regarding for example weather and energy use. Electricity produced in the solar panels can then be directed to residential use, the energy storage, the external grid or to run heat pumps. This also means that there is a link between the electrical grid and the heat system in the buildings, and that energy can be used and stored in the way that is most feasible.

10.1.3 *Procurement of equipment and/or services*

There are currently no planned purchases for this measure. However, some contracts have already been made to ensure the delivery of this measure, but where not all costs have been taken yet.

10.2 Societal, user and business aspects:

The system is intended to put the generated energy to use in the most efficient way possible, and to manage power peaks in a sustainable manner. Even if electrical power line congestion now is a smaller problem in Gothenburg than in other parts of Sweden, local electricity generation and smart use will be crucial as more and more electricity will be used. There are also parts of the district heating system in Gothenburg where congestion can be a problem, and the possibilities to change between district heating and heats pumps can therefore help the system. The automatic controlling system will also allow for energy to be used in the most efficient way possible, especially when electricity and heat are interconnected. For the city of Gothenburg this combination and flexibility means that the district heating grid and the electricity grid can be operated in the most effective way from a system perspective.

10.2.1 *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.

10.2.2 *Business model*

These are the foremost influential factors that influence the ability to monetize solutions like this, and how they are planned to be assessed.

Scalability
Future results will give some insights if this measure is scalable. In principle it could be scalable in different ways: either by building smaller systems like the one at Viva and interconnecting them, or by building larger scale systems that cover a larger residential area. The research that is planned at Viva could possibly shed some light on this in the future.

Interoperability

As the project looks at the infrastructure from several different perspectives, interoperability between different subsystems and with the grid will become evident as time passes.

International potential
As increased urbanization is a trend all over the world, the need for and interest in local energy management systems should be abundant.

10.2.3 *Governance*

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

Göteborg Energi is responsible for the equipment in the energy storage room and energy system therein;
research is conducted in cooperation with RISE, Riksbyggen, Volvo and Johanneberg Science Park. Volvo Buses will supply the batteries and Riksbyggen provides infrastructure, solar cells and the physical space for the electrical energy storage. Johanneberg Science Park will communicate with regards to similar projects in the area. Volvo has a separate project with focus on second life for batteries together with Stena Metall, Chalmers and the Västra Götaland region.

10.3 Impact Assessment

10.3.1 *Expected impact*

With a successful implementation of this demonstrator, we expect to see:

- A management system that can consider multiple energy sources, storage opportunities and variables of value to optimize the usage of a building, providing
- Lower cost for the consumers, in this case the housing association,
- Improved self-sufficiency on energy,
- And ultimately less carbon emissions from the city-wide energy system.

10.3.2 *KPIs*

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

Table 18. Summary-list of KPIs and related parameters for Measure 6

KPI	Parameter(s)	Baseline	Target
Degree of energy self-supply by RES	Thermal energy demand [Wh]	The first service year of brf Viva.	The optimization will probably reduce the thermal self-sufficiency from 100%
	Purchased thermal energy [Wh]		

	Electricity demand [Wh] Purchased electricity [Wh]		to 50 %, and increase electrical self-sufficiency from 25% to 35%.
Peak load reduction	Purchased thermal energy [Wh] Mean CoP in the heat pumps [-] Electricity demand [Wh] Purchased electricity [Wh]	The baseline is the peak electricity consumption plus heat consumption (divided by mean COP).	By using DH, the electricity peak can be diminished although the DH peak is unaccounted for. The system might not be programmed to lower the peaks.
Reduced energy cost for consumers	Purchased thermal energy [Wh] Cost rates of purchased thermal energy [€/Wh] Purchased electricity [Wh] Cost rates of purchased electricity [€/Wh]	Costs without acting EMS. This will be calculated continuously.	Viva will save money each year.
Carbon dioxide emission reduction	Electricity demand [Wh] Purchased thermal energy [Wh] Purchased electricity [Wh] Produced electricity in PVs [Wh] Hourly carbon intensity of the DH grid [g CO_2-e/Wh] Hourly carbon intensity of the electricity grid [g CO_2-e/Wh]	Carbon emissions from all bought energy during the first service year.	This is a bit complicated, so we will work on this and have a rough estimate in fall.
Increased system flexibility for energy players stakeholders	Peak purchased thermal energy [W] Peak purchased electricity [W] Installed capacity of flexibility providers: - Heat pumps - Battery storage - Accumulator tanks [W]	Zero flexibility.	The system flexibility might increase to 155% for district heating, and to 150% for electricity.

10.3.3 *Monitoring plan*

Monitoring 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. They are also part in IRIS and another cooperative research project dealing specifically with advanced energy management.

10.4 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 constructor in charge of that particular piece of the building has to keep working to deliver the promised results.

Table 19 Commissioning plan for Measure 2

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,	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		Riksbyggen – CFAB	Primary contract to finalize financing	

		CFAB – Housing association Viva	Primary contract for running energy trade	
4 Realization	Oversee and coordinate work	Coordinating contractor k21	Build	
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
	Test of function	Representatives from all companies involved in realization of measure	Testing of all systems, sub-systems and components.	
6 Completion	Start of trade			

10.5 Implementation plan

10.5.1 *Planning of activities*

During the first service year, the system will be optimized to minimize the amount of purchased energy to get a building certification. For this, the advanced EMS is not necessary and will not be deployed. The status of the management to days date is that it is under development on schedule. Also, calculations are done on the side of the energy system to amass data to prepare for the evaluation.

10.5.2 *Risk management*

Table 20 Risks and mitigation activities for Measure 6

Risk	Mitigation Activity	Probability	Impact	Comment
Batteries degrade too quickly	Close monitoring of the batteries. Even service in constant temperature with charge and discharge power.	Low	Low	
The comfort of	Review the use-cases of the EMS	Low	Low	

the residents is compromised	with user comfort in mind. Inform residents about the future benefits of having a more optimized EMS.			
Automatically generated signals prove impossible to make functional	Plan for redundancy in the system.	Low	Medium	The signals are programmed by a subcontractor to GE

10.5.3 *Progress achieved up to M24*

The battery storage and the first third of the solar power energy were installed by November 2018, and the remaining solar panels were added during the spring of 2019. The research began small-scale during 2019 and develop further by 2020, i.e. the Management is not operational but expected to be so in the middle of 2020.

10.6 Conclusion

There have been some problems with getting all the communication between the building and the energy management system to work correctly, which has resulted in unexpected delays. Naturally, it is important that the communication works without problems when the system is up and running, which is expected to be solved soon. Future installations of the same kind will include more time than planned for in this case.

All the installations in the building are ready for the advanced control system, it is just the programming of the system that needs to be fully developed.

Some issues when communicating between levels of contractors and subcontractors have occurred. This has made it harder to acquire information or being in coordinated in terms of progression, which has caused some delays.

11 Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process

This measure assesses the technical and economic feasibility of BIPV in renovation applications.

Building integrated solar power plants (BIPV) have the potential to be the cost-effective first choice for both roof and facade materials for new buildings and within renovation projects. BIPV, in this context means that other building materials are replaced by solar cell modules, typically roof tiles and facade panels. Basically, the solar modules behave like laminated glazed facade elements: strong and maintenance-free.

HSB Living Lab was built as a mobile building with four floors. One dwelling with student housing and an exhibition part where there are offices, meeting rooms, showroom for research results, laundry studio, and more. New technological and architectural innovations will be tested there under 10 years.

The aim of the project is to build up knowledge of

- technical and economic aspects of BIPV installations
- technical analysis/measurement of relative humidity (% RH) and temperature in the air gap behind solar modules

11.1 Specifications

The installation was designed based on budget, available space, HSBs wishes and aspects of research. There were 5 BIPV facilities with two different solar cell technologies on three facade sides and one BIPV plant on the roof. During the work interest from HSB was made to include a battery in the installation, which was also incorporated.

11.1.1 *Hardware*

A breakdown of all parts of the project including estimated investment cost before procurement listed below:

Solar panels (A-Si and mono-Si) at the façade south/east, about 3.5 m², 35 850 SEK

10 pieces. GS-50	1 250 SEK
4 pcs. Solitek	5 600 SEK
Inverters (µ)	7 000 SEK
Mounting system	2 000 SEK

Design / planning	5 000 SEK
Mounting (incl. Cable lift)	10 000 SEK
Electrical installations	5 000 SEK

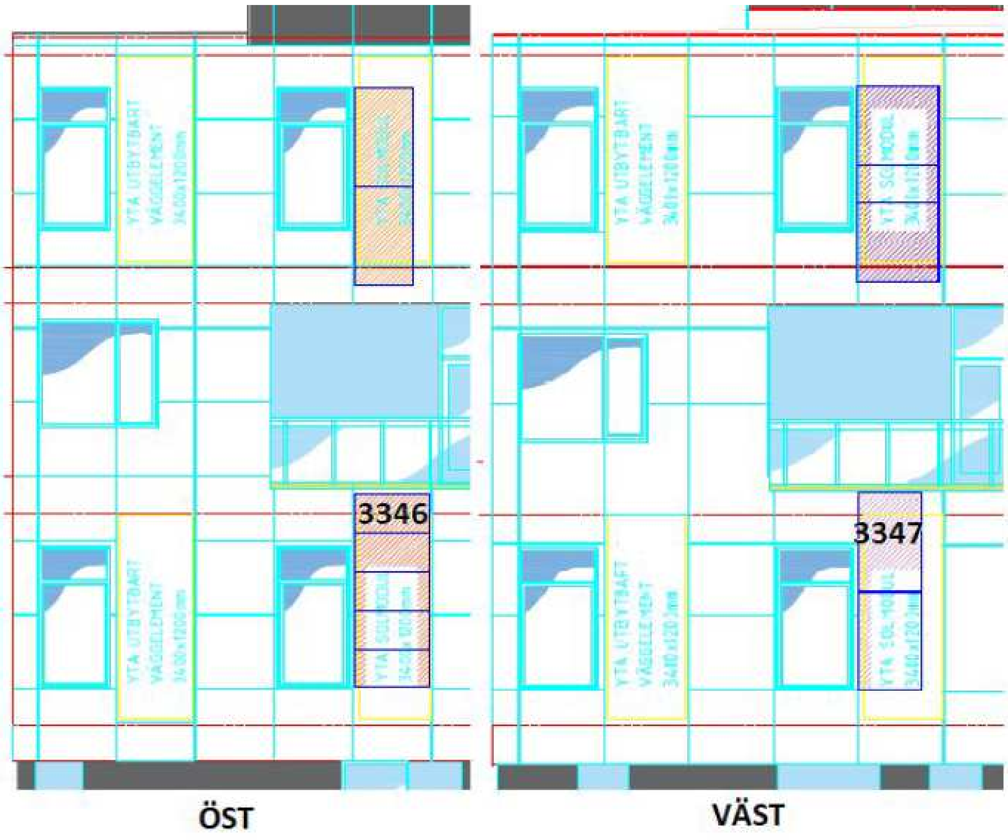


Figure 10 Solar panels (A-Si and mono-Si) at the façade south/east

Solar panel (A-Si) at the façade south, approximately 140 m², 127 625 SEK

164 pcs. GS-50 a-Si modules	20 625 SEK
Dummies, plate	6 000 SEK
1 piece Ferroamp SSO	4 000 SEK
Design / planning	5 000 SEK
Mounting system	12 000 SEK
Demolition + assembly	70 000 SEK

Electrical installations	10 000 SEK

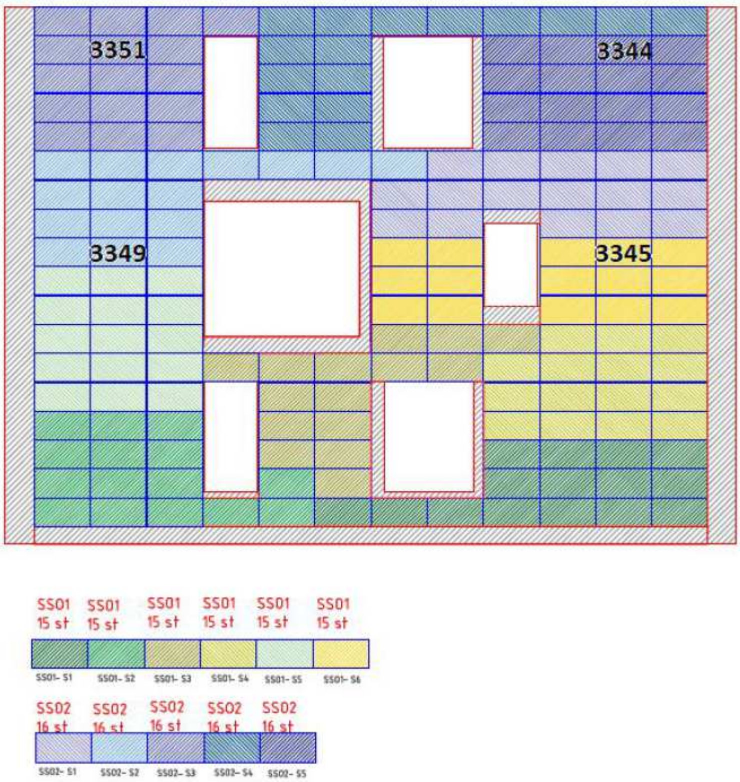


Figure 11 Solar panel (A-Si) at the façade south

Solar panels (Mono-Si) on the roof, approximately 50 m², 184 600 SEK

30 pc, 280 Wp, 60 cell mono-Si	48 600 SEK
1 piece Ferroamp SSO	4 000 SEK
Design / planning	5 000 SEK
Mounting system incl. roof trusses,	
raw shovel, canvas	40 000 SEK
Assembly and building	75 000 SEK
Electrical installations	12 000 SEK

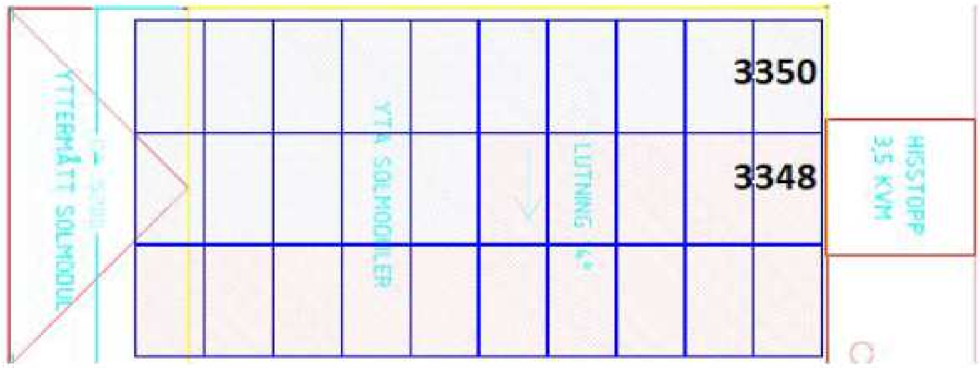


Figure 12 Solar panels (Mono-Si) on the roof

Misc

FerroAmp Energy Hub of 14 kW AC	23 000 SEK
FerroAmp battery, 7.2 kWh	75 000 SEK
Total BIPV installation at HLL	**446 075 SEK**

With the help of the following sensors the project expectation was that an evaluation of the various parts of the plant can be carried out:

- Temperature and relative humidity (% RH). Location according to Appendix 1.
- Inverters and DC-DC optimizers that log power, voltage and current for each sub-plant with high time resolution.
- Weather station on the roof with sensors (existing).
- Weather station

11.1.2 *Software*

For monitoring of energy production HSB Living Lab uses Ferroamp Portal[2]. See pictures below:

[2] https://portal.ferroamp.com/

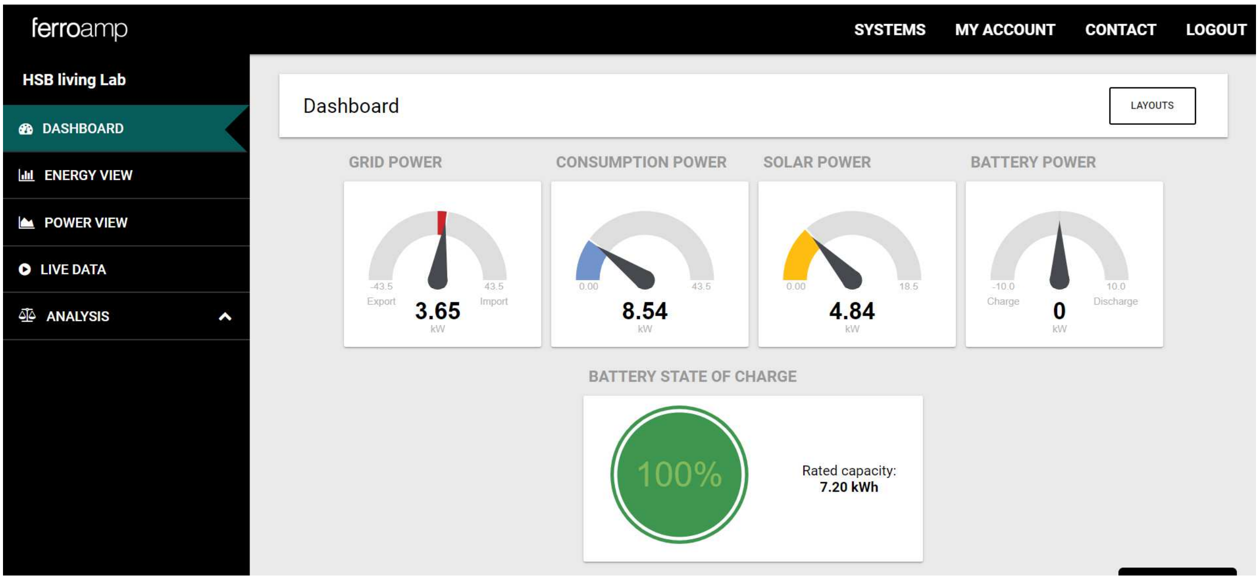


Figure 13 Ferroamp Portal 1

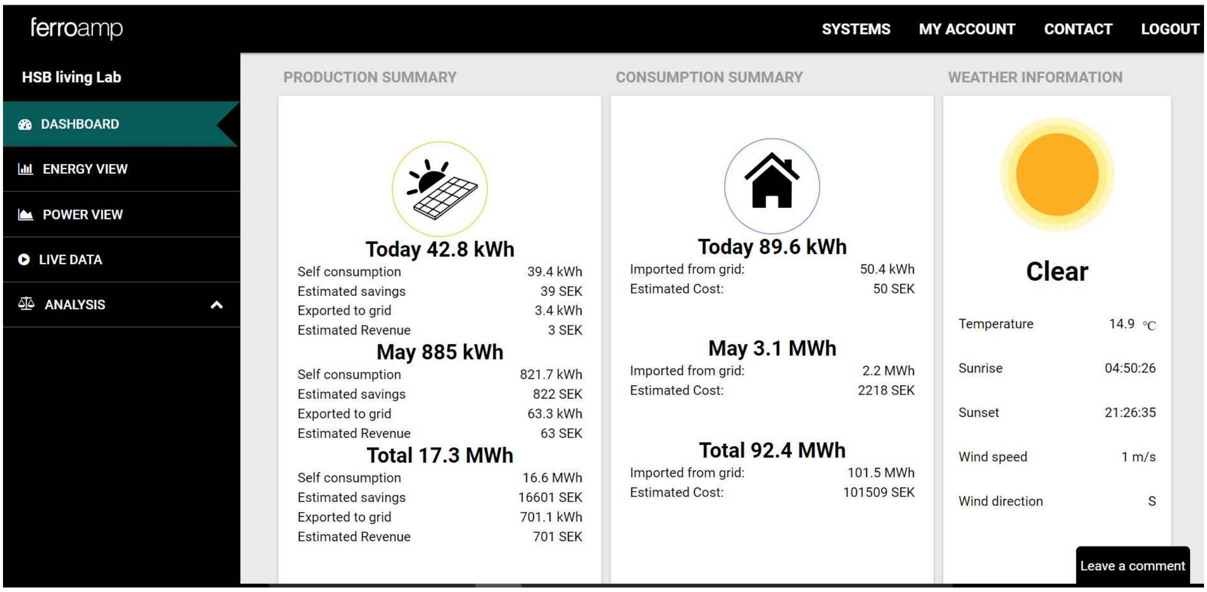


Figure 14 Ferroamp Portal 2

11.1.3 *Procurement of equipment and/or services*

There are currently no planned purchases for this measure.

11.2 Societal, user and business aspects:

11.2.1 *Citizen engagement*

The ability for tenants to view the energy portal "Ferroamp" is in progress. The goal is to display the portal on an existing information screen at the entrance.

11.2.2 *Business model*

Expected and actual annual production (kWh per year) can be found in the table below.

Table 21 Expected (typical year) and actual annual solar production 2017-10-01 - 2018-09-30.

	Expected yearly production, kWh	Actual production
Facade, east a-Si	123	105
Facade, west a-Si	156	163
Facade, east mono-Si	277	0
Facade, east mono-Si	343	0
Facade, south a-Si	5 261	4 146
Roof, mono-Si	8 094	7 026
Total	14 254	11 440

Some explanations for the approximately 21% lower production from the southern façade and 13% lower from the ceiling can be (in order from most to least likely according to our assessment):

- Shading on the southern façade is complex and difficult to model properly
- Malfunctions and other problems with the higher voltage equipment (e.g. facade).
- Overheating of SSOs
- Incorrectly connected modules or deviating modules (defective).

The effect of shading when modelling was not done correctly during the first design, which lead to a too high estimation of the expected production. The modelling is now done in a more detailed manner (in NREL's System Advisor Model, with 3d shading) and expected production is shown in table 11.

Comparison with typical and current solar radiation data (picture3) from SMHI's weather station at Chalmers shows that the annual period beginning October 2017 has had approximately 8% higher global horizontal solar radiation than a typical year (2007-2016) according to PVGIS5 satellite data. Unfortunately, all the weather stations at HSB Living Lab have been disconnected for almost the entire period as the plant has been in operation so we do not have compared to their data. The a-Si facilities on the east and the western façade performs as expected, suggesting that it is shading or the higher voltage and technical problems with the equipment on the southern facade which is the most likely explanation for it reduced production. The deviation (i.e. reduced production compared to the model) on the roof is difficult to explain. Analysis with an IR camera is a proven way to troubleshoot error connections or modules defective.

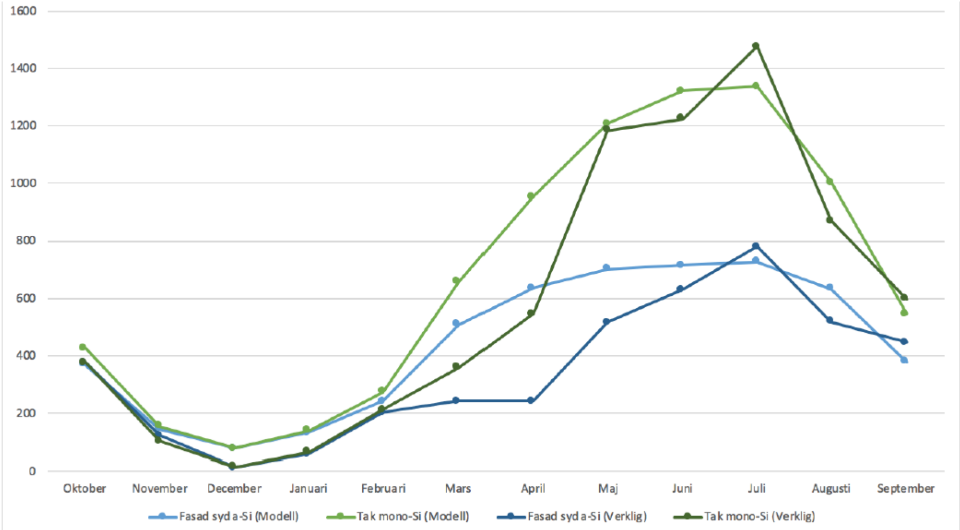


Figure 15 Expected (with improved modelling) and actual annual solar production 2017-10-01 - 2018-09-30, Facade (south) and Roof

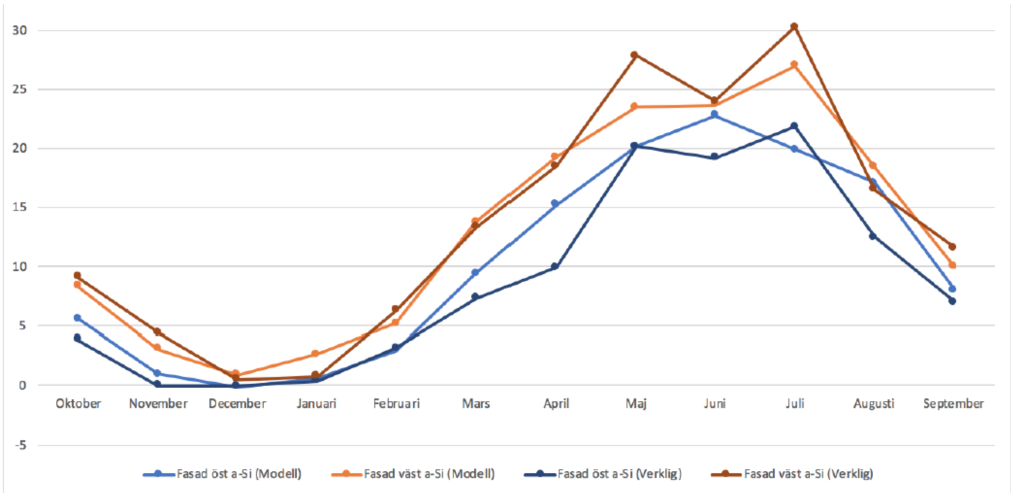


Figure 16 Expected (with improved modelling) and actual annual solar production 2017-10-01 - 2018-09-30, Facade east and west

Two days are compared in picture 11 below with observation data from SMHI (Swedish Meteorological a Hydrological Institute). Interesting is that the temperature behind solar cells on the facade quickly reaches up to over 50 ° C under direct sunlight when outdoor air temperature is only 13 ° C.

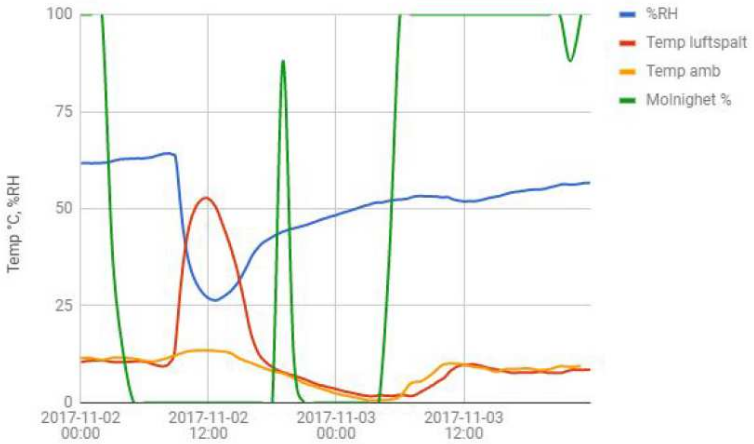


Figure 17 Temperature changes during two day in November

Time series of relative humidity and the temperature behind solar cell modules on the roof and the south the facade is shown in picture 12. It is worth noting a possible explanation for the high relative humidity under the roof at the beginning of the time series may be due to solar cells that were missing at first the final inspection and operated a little later than the others. The roof construction was therefore relatively unprotected from rain during this period.

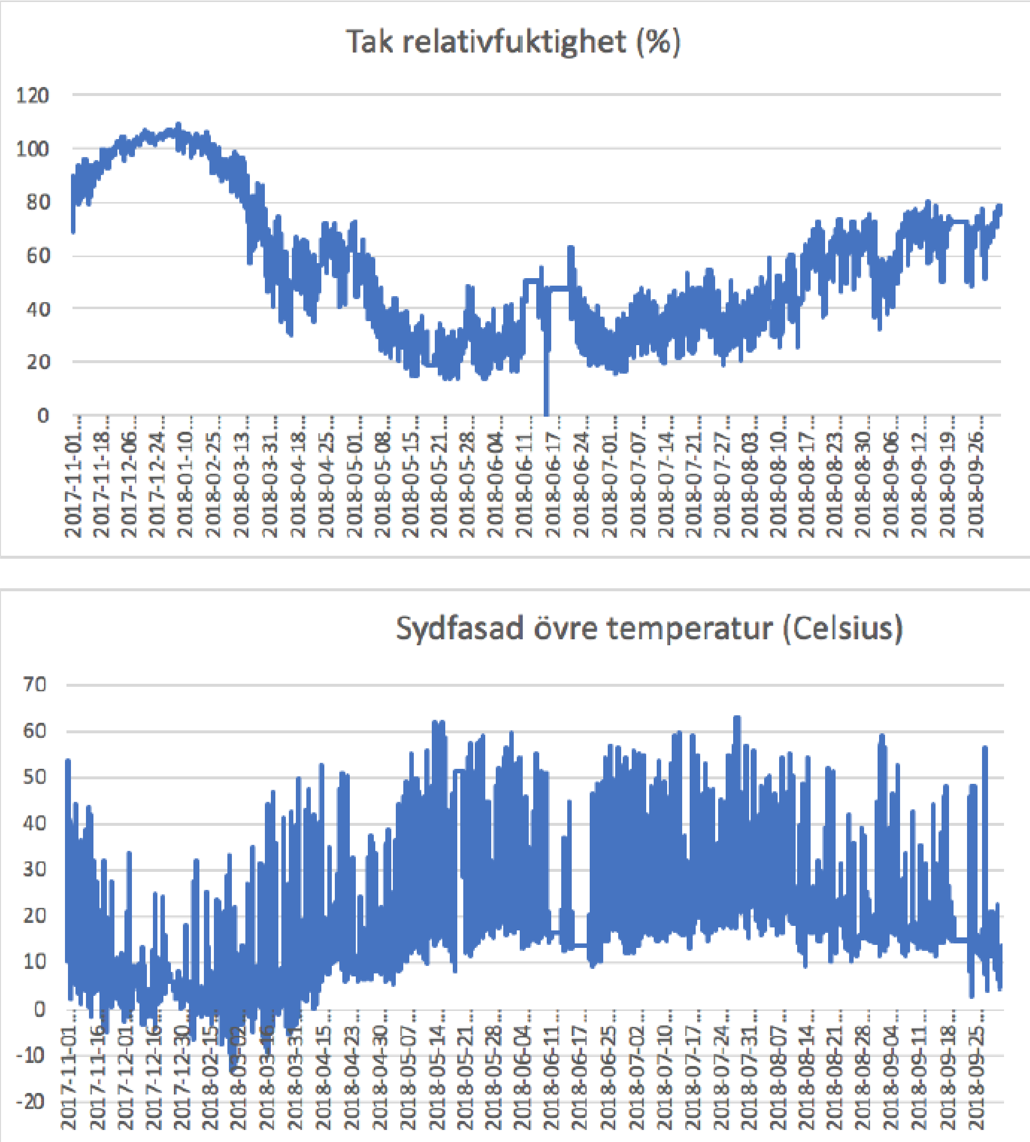


Figure 18 Relative humidity and the temperature behind solar cell modules on the roof and the south the facade

An evaluation and comparison of the cost of a BIPV facade with the original facade was produced in this project. Information from contractor that built the original façade consisting of Formica panels:

- Material cost facade panel approx. SEK 340 / m²
- Mounting time incl. Control and adjustment for windows and door, approx. 50 min / m²

Including labor costs of SEK 500 / hour, this gives a facade cost of approximately SEK 757 / m² (excl. VAT)

A comment from Merasol about the installation gives an insight into the most difficult steps in the assembly:

- *" Mounting only the southern façade including panels, Formica panels around windows, cables and inverters took about 200 h. If they had done the same wall again, they think it had taken less hours approximately 170 h (170 panels).*
- *The time needed for assembly the solar panels depends very much on how many windows there are and how much dummy's need to be mounted.*
- *East and west facades took about 50 hours (14 panels with complicated wiring) and the ceiling about 100 hours including building the roof construction. (30 panels)*
- *What would make it faster is another design on the clip that was used so that the distance between the panels is easier to get to! So, it's a good lesson for the next project!"*

Merasol, contractor HSB Living Lab BIPV project.

The BIPV facade mounted on HSB Living Lab had approximately the following costs:

- Material cost a-Si solar module 140 SEK / m²
- Mounting time incl. complementary regulation, adaptation for windows and door, connection of cables about 85 min / m²

Including labor costs of SEK 500 / hour, this gives a facade cost of approximately SEK 848 / m² (excl. VAT)

BIPV facades can generally be estimated by having approximately the following costs based on data from Merasol:

- Material cost a-Si solar module 200 SEK / m²
- Mounting time incl. complementary regulation, adaptation for windows and door, connection of cables about 73 min / m²

Including labor costs of SEK 500 / hour, this gives a facade cost of approximately SEK 808 / m² (excl. VAT)

11.2.3 *Governance*

HSB is sole owner of both the building HSB Living Lab and the BIPV system, and thus have full authority over any alterations or additions.

11.3 Impact Assessment

11.3.1 *Expected impact*

With a successful implementation of this demonstrator, we expect to see:

- Reduced energy cost as well as climate forcing when providing the residents of HSBLL with a comfortable indoor environment.
- Lower investment cost as well as reduced material use when adding PV systems to other buildings, when renovations would any way take place.
- Based on these two, a new renovation model for improving the energy performance of buildings.

11.3.2 KPIs

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

Table 22. Summary-list of KPIs and related parameters for Measure 7.

KPI	Parameter(s)	Baseline	Target
Increase in local renewable energy production	Electricity production by BIPV in HSBLL [Wh]	0 MWh per average year	14 MWh
	Electricity usage in HSBLL [Wh]		
Degree of energy self-supply by RES	Electricity production by BIPV in HSBLL [Wh]	0 %	19 % of electricity used in the building
	Electricity usage in HSBLL [Wh]		
Carbon dioxide emission reduction	Electricity production by BIPV in HSBLL [Wh]	0 tonnes	0,525 tonnes CO_2 reduction
	Electricity usage in HSBLL [Wh]		
	Carbon intensity of the electricity grid [g CO_2-e/Wh]		
CO2 reduction cost efficiency	CO_2 Emission Reduction [tonnes/year]	N/A	N/A
	Investment cost [€]		
	Service life [years]		
	Running costs [€/year]		

11.3.3 Monitoring plan

Monitoring is conducted continuously until 2025. Energy production will be evaluated from different perspectives such as: 1. Production compared to different weather conditions such as solar radiation/temperature. 2. Eventual decreased production caused by the age of the system. The monitoring is done by HSB.

11.4 Implementation plan

11.4.1 Planning of activities

Next step is to package a replicable business model. This is intended to be easily used by housing developers.

11.4.2 *Risk management*

No major risk identified.

11.4.3 *Progress achieved up to M24*

Installation of the solar cells was executed according to plan. The plant is in operation since end of September 2017, except for four minor solar cell modules on the east and west facades that were never activated caused by design mistake, but the amount of energy from the activated part of the plant can be compared with expected production.

11.5 Conclusion

The conclusion from this analysis is that a BIPV facade is **not** more expensive than an ordinary facade material when using thin film solar cell technology. Such solar cell technology is also better for the environment according to life cycle analysis. The fact that the façade produces energy will in the long run make it much more profitable to invest in BIPV than ordinary facade materials. The project also has demonstrated that a BIPV solution on the roof is possible with relatively simple mounting methods. Comparison with solar radiation data from the weather stations mounted on HSB Living Lab did not become relevant. The weather stations were disconnected for various reasons during almost the entire evaluation period.

A comparison with typical satellite solar radiation data and a weather station on the Johanneberg campus has given a somewhat complete picture of the performance of the plant. A more detailed analysis and continued troubleshooting could lead to an explanation for the approx. 16% reduced annual solar production compared to the expected result during modelling. If one considers that the year was somewhat sunnier than a typical year (8% according to the weather station) then the deviation is even greater.

It would be useful to evaluate the two solar cell technologies that was planned and do the analysis with data from the weather station data to be able to dig into the details regarding why there was a deviation in energy delivery. Hopefully this project will lead to several renovation projects and new constructions where BIPV technology is used.

Monitoring, moisture and other types of evaluation, creation of business models and replication activities are the next steps for this demonstrator within IRIS.

12 Summary on monitoring of KPIs

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

In Viva, the monitoring period has only just begun now that the construction has only been finished for a few months. 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.

The monitoring in HSB Living Lab is completed and covered in chapter 11 above.

12.1 Expected impact

While ensuring a reliable, comfortable and efficient supply of electricity and heating for the residents of Viva and HSBLL, 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.
- Increased energetic self-sufficiency, from renewable energy sources.
- An overall relatively low cost, when considering how the measures would perform in representative replication applications.
- 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.

12.2 Aggregation of KPIs for Gothenburg

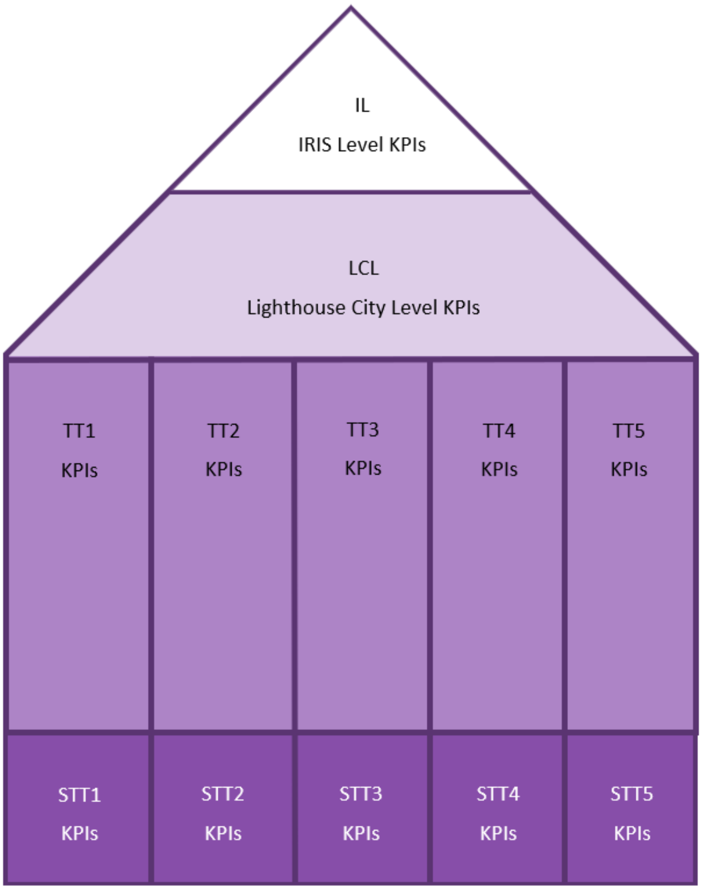


Figure 19 IRIS KPI-house. The KPIs presented in Tables 4-6 are, if possible, aggregated to transition track level (TT1-5) or higher.

12.2.1 Gothenburg

Table 23. Relation and possible aggregation of KPIs to solutions and the IRIS KPI-house in Figure 19.

KPIs	Solution	Proposed position in IRIS KPI-house
Carbon dioxide Emission Reduction	All solutions in this report: Demonstration of at least 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV Demonstration of heating from geo energy with heat pumps (2-300 m deep boreholes) Demonstration of cooling from geo energy without chillers Demonstration of local energy storages consisting of water buffer tanks, structural (thermal inertia of the building) storage and	IL

	long-term storage in boreholes Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block 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 Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process	
Degree of energy self-supply by RES	Demonstration of at least 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV Demonstration of heating from geo energy with heat pumps (2-300 m deep boreholes) Demonstration of cooling from geo energy without chillers 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 Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process	TTL
Energy savings	Demonstration of at least 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block	TLL
CO2 reduction cost efficiency	Demonstration of heating from geo energy with heat pumps (2-300 m deep boreholes) Demonstration of cooling from geo energy without chillers Demonstration of local energy storages consisting of water buffer tanks, structural (thermal inertia of the building) storage and long-term storage in boreholes Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process	SL

Storage capacity installed	Demonstration of local energy storages consisting of water buffer tanks, structural (thermal inertia of the building) storage and long-term storage in boreholes	TLL
Peak load reduction	Demonstration of local energy storages consisting of water buffer tanks, structural (thermal inertia of the building) storage and long-term storage in boreholes Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block 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	TLL
Reduced energy cost for consumers	Demonstration of seasonal energy trading (cooling in summer season) with adjacent office block 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	SL
Increased system flexibility for energy players stakeholders	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	SL
Increase in local renewable energy production	Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process	TTL

13 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.

13.1 GDPR compliance

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

13.2 Ethical aspects

No specific ethical aspects apply to these measures.

14 Links to other work packages

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

- The energy system in Viva has two measures in TT#2.
- The mobility measures in Viva are covered in TT#3.
- HSBLL houses one of the measures in TT#4.

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

15 Conclusions and next steps

In Brf Viva, there are mainly two cases. Either the launch has been impossible, as for measures 3 and 5, or it has gone about as smooth as hoped, as for all the rest. The impossibilities relate to measures 3 and 5 being planned in cooperation with another real estate owner as well as having encountered issues making them substantially more expensive than anticipated. Besides that, 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?

In HSB Living Lab, the main conclusion is that this kind of thin film BIPV facade is **not** more expensive than an ordinary facade material, and it is also better for the environment according to life cycle analysis. The continuous electricity generation is indeed a sound argument for the investment decision. Also, a BIPV solution on the roof is possible with relatively simple mounting methods.

The next steps include monitoring, moisture and other types of evaluation, creation of business models and replication activities.