EXCESS

FleXible user-CEntric Energy poSitive houseS

Deliverable D4.1:

Performance evaluation handbook of PEB solutions

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Abstract
The Performance evaluation handbook of PEB solutions is describing principles of performance evaluation of positive energy building (PEB) solutions. The document first provides an overview of commonly used key performance indicators (KPIs) used for the evaluation, first at general level and then focusing on the demo case studies in four countries (Finland, Belgium, Spain and Austria). Furthermore, the measurement plans for the demo plans are described including the goals and technical details. The main goal in each case is to implement PEB level building with high energy performance. The cases include sub-goals related to new technology solutions and their performance. In the energy domain the main focus of the EXCESS project was in renewable share, self-consumption rate of local renewables and self-sufficiency ratio describing the share of own local production compared to demand. The energy flexibility and CO_2 emissions were seen as a big value for energy positive buildings. In the economic domain the capital costs, operational costs, life-cycle costs and global costs were recognised as most important key performance indicators. In the technology domain indicators, seasonal coefficient of performance is describing performance and efficiency of the technology and gives a good indicator for development of the technology. Robustness and stability were seen as basic requirements for the energy systems. Concerning the social indicators, the variety of KPIs is large, which leaves the selection for each case separately. User satisfaction, comfort and visibility of the results were recognised as the main indicators. The results from the internal EXCESS workshop and associated tables were given as information and checklist to the demos, which made their own selections for specific cases.

Keywords
PEB, positive energy buildings, evaluation, monitoring, KPI, key performance indicators

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EXECUTIVE SUMMARY

This report - Performance evaluation handbook of PEB solutions - describes the principles of performance evaluation of positive energy building (PEB) solutions. The document first provides an overview of commonly used key performance indicators (KPIs) used for the evaluation at a general level and then focusing on the demo case studies in four countries (Finland, Belgium, Spain and Austria). Furthermore, the measurement plans for the demos are described including the goals and technical details. The main goal in each case is to implement a PEB level building with high energy performance. The cases include sub-goals related to the new technology solutions and performance.

The Finnish demo case is a residential house at Kalasatama, Helsinki, targeting to a building which is producing as much local renewable energy as is needed for heating, ventilation and domestic hot water at yearly level. The Kalasatama house is demonstrating the performance of semi-deep geothermal system integrated with heat pumps, PVs at facades, PVT panels on the roof, ventilation cooling and high COP domestic hot water systems. Demand based ventilation has high efficiency heat recovery and energy systems are controlled with smart control and an optimisation system.

The Belgian demo case is part of a residential area in Hasselt. The project consists of 68 apartments and 22 houses intended for social housing. The residential units are connected to a small district heating network which is heated by different thermal energy sources (geothermal heat pumps, gas-fired geothermal heat pumps and backup gas-fired boilers). The building will be converted to a positive energy building. This will be achieved by implementing innovations developed within the EXCESS project: PVT panels for renewable heat and electricity, multi-source and direct controlled heat pump, MPC controller (model predictive controller) for optimization of the energy flows onsite and activation of thermal and electrical flexibility in the heat interface units within the apartments.

The Spanish demo case is located in the historical centre of Valladolid and it is a protected classical Renaissance palace (XVI century). The project consists of an entire renovation of the internal distribution of the building to create nine dwellings. Due to the heritage protection of the building, to minimize the energy demand, the envelope of the building must be upgraded without modifying the exterior appearance of the façade, including the size, number and position of the windows. In addition, high performance HVAC systems will be installed, as well as the renewable energy systems that the architectural protection allows. The planned demonstrated technology includes integration of air heat pump system, PV and PVT panels, Ion-Lithium batteries for electricity storage and eV (electric vehicle) charging stations. The integrated controller, human-machine interface system and building energy management system are used for deciding the strategies for energy sharing and trading.

In the Austrian demo case, a former commercial zone is transformed into an area with mixed use, including offices, recreation zones as well as sports facilities and restaurants. In total, the 19 buildings in the area are being refurbished towards passive house standards while increasing the share of locally produced renewable energy (solar energy, small hydropower). Through the integration of innovative elements for load shifting, storage, user integration, interaction with the local electricity grid as well as a smart, predictive control, a maximum energy flexibility will be achieved, and the self-consumption will be increased. The EXCESS demo building consists of ten floors, with a cafeteria in the basement and office space with temporary overnight accommodation. Several energy efficiency measures will be integrated, including a multifunctional façade (electricity generation, heating and cooling) that can be mounted to the exterior of an existing building to improve its energy performance. The hybrid energy system combines a cascading heat pump system, PV panels on the roofs and façades and a

small hydro power plant that will produce electricity and heat for the building. Energy flexibility in the building is also maximized by thermal building mass activation, and decentralized buffer storages. User centric applications will be a key innovation to facilitate the creation of an energy community. The application allows constant monitoring and verification of energy savings at the prosumer and the building levels and facilitates the transparent distribution of benefits arising from energy optimization among prosumers based on energy measurements handled through blockchain.

The four demo cases have several common targets and KPIs for showing the performance of PEBs. As one of the first steps in EXCESS project, a common definition of PEB was developed: "*EXCESS defines a positive energy building (PEB) as an energy efficient building that produces more energy than it uses via renewable sources, with a high self-consumption rate and high energy flexibility, over a time span of one year. A high-quality indoor environment is an essential element in the PEB, maintaining the comfort and well-being of the building occupants. The PEB is also able to integrate future technologies like electric vehicles with the motivation to maximize the onsite consumption and share the surplus renewable energy.*"

The main interests of the EXCESS demo groups were elaborated in an internal workshop. In the energy domain, the biggest interest was in renewable share, self-consumption rate of local renewables and self-sufficiency ratio describing the share of own local production compared to demand. The energy flexibility and CO_2 emissions were seen as a big value for energy positive buildings. In the economic domain, the capital costs, operational costs and life-cycle costs were recognised as key performance indicators. In the technology domain, the seasonal coefficient of performance is describing performance and efficiency of the technology and gives a good indicator for development of the technology. Robustness and stability were seen as basic requirements for the energy systems. Concerning the social indicators, the variety of KPIs is large, which leaves the selection for each case separately. User satisfaction, comfort and visibility of the results were recognised as the main indicators. The workshop results and associated table were given as information and checklist to the demos, which made their own selections for the cases.

The common KPIs for all four cases (4/4) or for at least three cases (3/4) are:

- Grid energy consumption showing the balance of grid injection and off-take (4/4)
- Local renewable energy production (4/4)
- Self-consumption rate (4/4)
- CAPEX – capital expenditures (4/4)
- OPEX – operational expenditures (4/4)
- Energy consumption – heat (3/4)
- Energy consumption – electricity (3/4)
- Self-sufficiency ratio (or load cover factor) (3/4)
- SCOP – seasonal coefficient of performance (3/4)
- Comfort (3/4)

The other KPIs were selected only for one or two cases. The selection of case specific KPIs showed the different approaches in different countries and projects. In general, it would be interesting to get all the KPIs from all the cases, but this is not possible due to the amount of measured data and questionnaire studies needed for these. For this reason, the final selection of KPIs was done separately for each case.

EXCESS

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1 Introduction

This work is part of WP4 in the EXCESS project. The overall goal of EXCESS WP4 is to demonstrate the ability of the PEB solutions (e.g. solar assisted multisource heat pump, PVT, ground seasonal storage and energy storages) to fulfil the end user's heating and cooling needs with a minimum ecological footprint. WP4 will demonstrate the principles and novel technologies and functionalities developed in WP2 and WP3 and uses the extended definition (techno-socio-economic-regulatory) of WP1 for defining the Key Performance Indicators (KPIs), which are created to facilitate an efficient comparison, common evaluation and reporting principles.

The key activities of WP4 are:

- Definition of qualitative and quantitative indicators KPIs aligned with T1.1 (PEB definition), project's goals, use cases, requirements and harmonised with SmartCity indicators to make them easily adoptable by replication actors
- Preparation and integration of the validation framework (setting up the demonstration cases)
- Demonstration of PEB technologies at demo sites from a broad perspective (technical, environmental, economic and social), showing the user behaviour (context-aware flexibility interactions) & societal impacts and market added benefits (local energy communities peer-to-peer energy transaction and flexibility trading)
- Define and collect the necessary data (monitoring) for the optimization and validation of proposed secure data-handling infrastructure
- Validate the technical and economic feasibility of the EXCESS PEB solutions
- Evaluate the results and make a synthesis of the key achievements of the project

The work described in this document focuses on the first bullet point in the list.

1.1 Purpose and scope of the document

This document presents the definition of qualitative and quantitative KPIs aligned with the PEB definition developed in Task T1.1, project's goals, use cases, requirements and harmonized with SmartCity indicators to make them easily adoptable by replication actors.

Deliverable D4.1 describes the data, measurements and instrumentation needed for the calculation of KPIs. The pathway from single measurements towards KPIs and energy balance of the building showing the energy performance is explained by the four EXCESS demo cases. This document serves as a handbook for the evaluation phase in Task T4.3 (Evaluation and validation).

The task description in the workplan:

Task 4.1 Evaluation method and Indicators (Leader: VTT Participants: VITO, JR, AEE INT, CENER, S5, TAS, CORDIUM, DS, MUOV, GEB M1-M42)

Key performance indicator matrix for each use cases of T4.1, identifying energy, economy and environment/ecology Key Performance Indicators (KPI) related to the project's goals and requirements will be defined. Partners will firstly define KPIs for assessing:

• integration potential in terms of easiness, robustness and smartness, building on the Smart Readiness Indicators project; single technology performances overall system performance (energy, longevity, ease of installation maintenance, bankability indicators); available energy flexibility,

• use and integration with existing building/network infrastructures

• environmental and energy savings assessments,

• indoor comfort quality

• cost of PEB solutions

• social acceptance, data safety and security issues

• stakeholders' satisfaction

and then localize them in accordance with demonstration site specifics. VTT will harmonize these with CITYkeys KPIs to make them easily adoptable by local authorities and smart city-solutions replication actors. A first version of the report "Performance evaluation handbook of PEB solutions" in M14, which includes the performance indicator matrix and KPIs definition, will be compiled. This draft will be used by local partners to extend the definition of the defined KPI with expressing evaluation/metrics (evaluation criteria and variables needed to calculate them) based on the technical solutions deployed on site. SUITE5 will supervise the evaluation/metrics for each demonstration site to ensure the integrity with the Data Management Framework of Task T3.2. VTT will collect contributions from local partners (TAS- Finland, CEN-Spain, AEE-Austria, CORDIUM-Belgium) as regard these extended KPIs definition and finalize the handbook with feedback from the demos.

1.2 Structure of the document and role of partners

Chapter 2 discusses the targets and key performance indicators (KPIs) of positive energy buildings starting from the definition of PEB. This chapter gives an overview of the general frameworks for building and district level indicators, e.g. CityKeys, Smart City indicator system (SCIS), SRI Smart Readiness Indicators. The KPIs in EXCESS have four perspectives: energy perspective (e.g. energy efficiency, RES integration, CO_2 emissions reduction, air quality), economic perspective (e.g. cost of technology and measurement, energy costs reduction, revenue streams from market transactions, business models viability, return-on-investment, payback period, net present value), social perspective (e.g. users engagement, user acceptance, comfort and indoor environmental quality, energy security of supply, number of new jobs created, data security and privacy) and technology perspective (e.g. system interoperability, conformance with standards, ICT solutions performance, compliance of functionality to the user requirements). The KPIs from the EXCESS viewpoint are summarised for the use in the monitoring phase. The KPI work in EXCESS focuses on giving a summary view of performance, but some subsystem level analysis is included, e.g. heat pumps, PVT panels, multifunctional facades and geothermal boreholes. The subsystem level evaluation is needed to guarantee the component level performance as part of the system.

Chapter 3 describes the targets, KPIs and measurements in four demo cases starting from the objectives and targets of each case from the viewpoint of building energy related issues. Each demo case explains the energy and building system implemented, selected KPIs and the measurement plans.

Chapter 4 gives EXCESS recommendations for the KPIs for PEBs and discusses the feedback and experiences on the demo sites.

Chapter 5 gives conclusions and proposes future actions on the topic.

The following partners have been active in giving input for the report:

- VTT – coordination of WP4 and Task T4.1 work and writing of D4.1, coordination of FIN demo case activities
- VITO, AEE, CENER, TAS – definition of demo specific KPIs and monitoring/measurements
- DS, MUOV, GEB, TAS – definition of KPIs, measurements and instrumentation related to their own products
- S5 - supervise the evaluation/metrics for each demonstration site to ensure the integrity with the Data Management Framework of Task T3.2.
- JR – specific role to check and define economic and life cycle KPIs

2 Targets and KPIs of positive energy buildings

2.1 Definition of PEB

As one of the first steps in EXCESS project, a common definition of PEB was developed, based on literature review and discussions among the EXCESS team (Ala-Juusela et al 2020). The following is the outcome of this work:

> EXCESS defines a positive energy building (PEB) as an energy efficient building that produces more energy than it uses via renewable sources, with a high self-sufficiency rate and high energy flexibility, over a time span of one year.
>
> A high-quality indoor environment is an essential element in the PEB, maintaining the comfort and well-being of the building occupants. The PEB is also able to integrate future technologies like electric vehicles with the motivation to maximize the onsite consumption and also share the surplus renewable energy.

- EXCESS mainly considers residential buildings, while looking at the role of the building in a bigger context, especially through impact on energy networks. In the assessment of the building, the energy needs for other than residential activities, e.g. commercial or public services are excluded, while the energy use for the shared spaces is included.

- The local generation includes the energy produced at the building site, with technologies placed in/on the building or building site and technologies incorporated within the building elements.

- The energy need components considered in EXCESS are heating, cooling and electricity. Heating includes both space and water heating. Electricity includes lighting, plug loads, ventilation and the electricity needs for the shared spaces such as lighting in common zones and elevators.

- EXCESS uses the definition of renewable energy from the European RES directive, which defines it as energy from renewable non-fossil sources, e.g. wind, solar, hydro, geothermal or biomass.

- A high self-consumption rate contributes to minimising both the emissions and the negative impacts to the grid. The self-consumption rate can be increased e.g. by demand response and energy storage solutions.
- The indoor environment consists of the thermal, visual and acoustic environment and indoor air quality.
- The life-cycle effects on costs and emissions should be considered in the planning and analysis of PEB.

The KPIs should be developed to verify how well the building and its systems comply with this definition. In addition, KPIs need to be developed to check the economic, social and technical viability and quality of the solutions.

2.2 Key Performance Indicators for PEBs – an overview

This chapter presents the KPI concept and frameworks that could possibly work as basis for the KPIs in EXCESS demos, e.g. CITYkeys indicator system, Smart City Indicator System (SCIS) and the Smart Readiness Indicators (SRIs).

The research sector has been very active in defining the performance indicators in the construction and the built environment sector. Figure 1 shows the pathway of projects where VTT has participated between 2007-2018 (some of the projects still going on in 2023) developing the indicators and approaches. The pathway has led to a holistic evaluation of the cases, considering several indicators and giving several methods to show the overall performance for different stakeholders. The challenge is in fact to find the most relevant KPIs for each purpose.

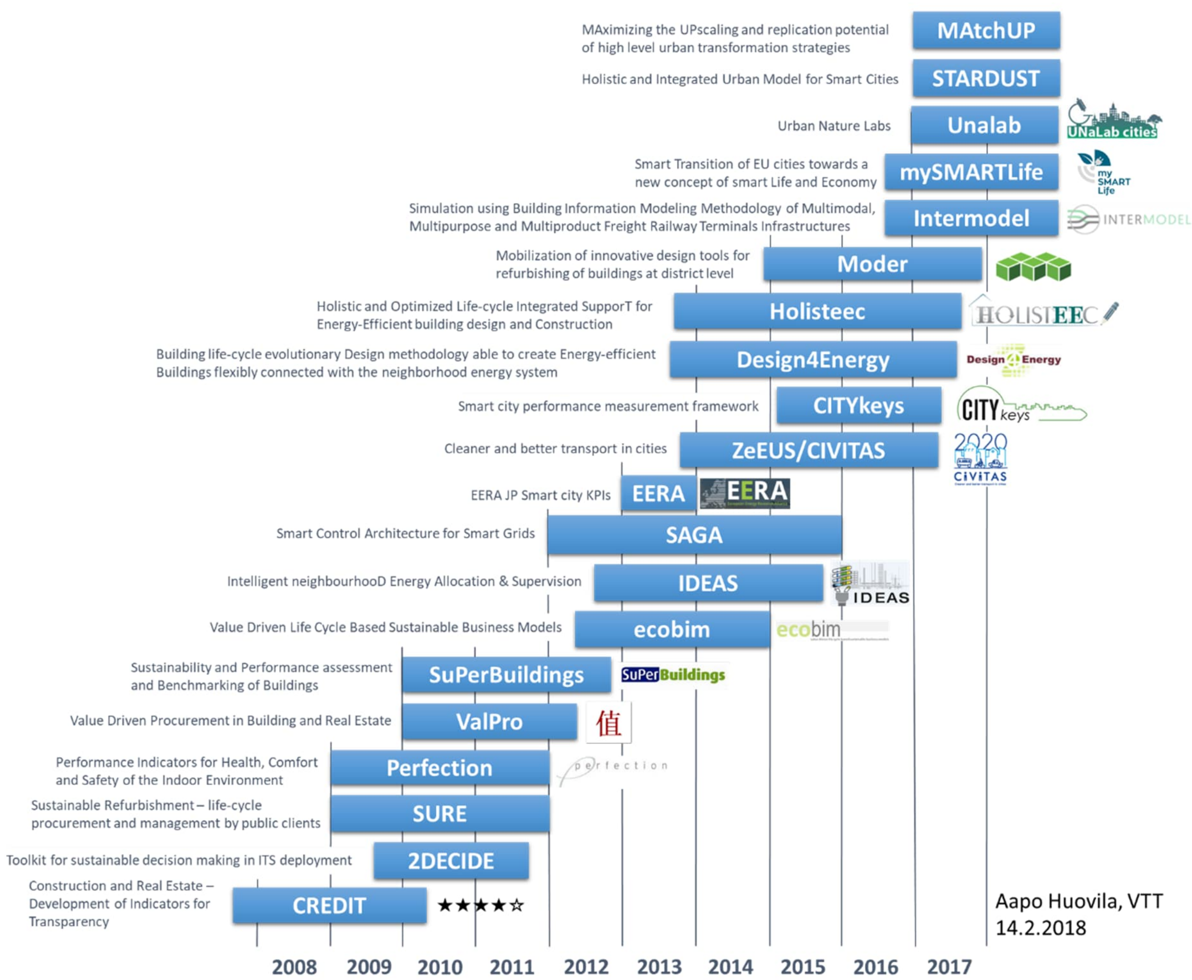

Figure 1. Roadmap of indicator related projects VTT has participated in 2008-2018.

The CITYkeys indicator system was developed in the CITYkeys project (Huovila et al 2017). The ultimate goal of CITYkeys was to support the speeding up of wide-scale deployment of smart city solutions and services in order to create impact on major societal challenges around the continuous growth and densification of cities while also placing a strong emphasis on climate change. CITYkeys aimed to facilitate and enable stakeholders in projects or cities to learn from each other, create trust in solutions, and monitor progress, by means of a common integrated performance measurement framework.

In the CITYkeys indicator system the indicators are based on four themes: people, planet, prosperity, governance and propagation which led to the development of 99 project indicators and 76 city indicators. The selection was based on an inventory of 43 existing indicator frameworks for (sustainable) cities and projects. The majority of the indicators in the CITYkeys selection has been derived from existing indicator frameworks. New indicators have been suggested to fill gaps in existing frameworks, mostly related to specific characteristics of smart city projects.

The relevant CITYkeys KPIs are listed in the tables in chapter 2.3 for the areas that are considered in the EXCESS project: energy related, economic, social and technical aspects.

The Smart City indicator system (SCIS) gives guidelines for KPIs, monitoring and reporting[1]. The documentation of the indicator system includes 8 reports giving methods and recommendations for

[1] https://smartcities-infosystem.eu/library/resources/scis-essential-monitoring-guides

different areas, including technical, social and economic monitoring, as well as examples of visualisation tools and best practices. The SCIS Key performance indicators Guide (SCIS 2018a) gives the core description of the system and KPIs, and the Technical Monitoring Guide (SCIS 2018b) gives more information on how to monitor and evaluate in practise. SCIS Self-reporting Guide (SCIS 2023) shows step-by-step how to report own case with SCIS tool. Table 1 presents the selected key performance indicators of SCIS system. The indicators were selected according to relevance to EXCESS PEB performance evaluation.

Table 1. Selected key performance indicators of SCIS system.

SCIS Indicator	EXCESS Domain
ES_T Thermal energy savings: ES_E electrical energy savings (simulated or monitored); E_D Energy demand (e.g. simulated); E_C Energy consumption (monitored); PE_D Primary energy demand (simulated); PE_C Primary energy consumption (monitored)	Energy
DE_T Degree of thermal energy self-supply based on RES, DE_E Degree of electrical energy self-supply based on RES	Energy
SF the amount of load capacity participating in demand side management [MW]. ΔSF is the percentage improvement.	Energy
Peak load reduction (%)	Energy
TE_D Thermal energy demand (simulated)	Energy
EE_D Electrical energy demand (simulated)	Energy
DE_T Degree of thermal energy self-supply based on RES, DE_E Degree of electrical energy self-supply based on RES	Energy
GGE Greenhouse gas emissions for buildings	Energy
I_{BR} Total investment for all the interventions related to energy aspects [€]	Economic
TAC Total annual energy cost of the reference system (i.e. energy, operation & maintenance) [€/yr] (before and after)	Economic
ROI_T Return on Investment [%]	Economic
EPP Economic payback [yrs]	Economic
Gr_{BR} Share of the investment in building retrofitting that is covered by grants	Economic
Number of final users involved, number of people with increased ability to manage their energy consumption	Social
dT_{fault} Average time needed for awareness, localization and isolation of grid fault.	Social
Increased Reliability: avoiding failures revert on higher reliability with the application of ICT measures (%)	Technical

The Smart Readiness Indicators (SRIs) were developed based on the idea that smart technologies in buildings have the potential to increase the operational performance of buildings, enhance the flexibility in smart energy grids, and improve comfort and health of building occupants.

The smart readiness indicator (SRI) was first introduced in the 2018 EPBD recast and endorsed in European legislation (European Union 2020a and 2020b), published in 2020 and came into force in January 2021. In this regulation an optional common European Union scheme for rating the smart readiness of buildings is established and the technical modalities for the effective implementation are detailed.

The current recast proposal of the Energy Performance of Buildings Directive (EPBD) (European Union; 2021) foresees reinforcement of the SRI for large non-residential buildings as of 2026. For all other building types and also before that time, the SRI is foreseen as an optional scheme, which means that Member States would be allowed to implement the SRI on (part of) their territory, for all buildings or only for certain categories of buildings. In contrast to EPC schemes, the general principles of the methodology, the assessment rules and criteria are shared among the member states, but specific elements are to be adapted to the local context by the Member States.

The proposal also contains requirements for independent control mechanisms similar to the mechanisms currently prescribed for EPCs and prescribes inclusion of the smart readiness indicators in the digital building logbook and in a publicly accessible national database.

The SRI is to be used to measure the capacity of buildings to use information and communication technologies and electronic systems to adapt the operation of buildings to the needs of the occupants and the grid and to improve the energy efficiency and overall performance of buildings. The SRI serves to raise awareness amongst building owners and occupants of the value behind building automation and electronic monitoring of technical building systems and aims to give confidence to occupants about the actual savings of those new enhanced functionalities.

The SRI rating is a measure for a building's capacity to accommodate smart-ready services. These services are categorized in 9 technical domains - space heating, cooling, domestic hot water, ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging, monitoring and control - and are assessed for a given building against 7 desired impacts in 3 main functionalities of building smartness; 1) Optimize energy efficiency and overall in-use performance; 2) Adopt their operation to the needs of the occupant and 3) Adopt to signals from the grid (energy flexibility).

The calculation of the smart readiness scores of a building or building unit relies on the assessment of the smart-ready services that are present, or planned at design stage, and on their functionality level.

For each service to be assessed, the functionality level is to be determined according to the catalogue of smart-ready services. For each impact criterion, a total impact score is calculated as the weighted sum of the domain impact scores. In this calculation, the weight of a given domain will depend on its relative importance for the considered impact. The maximum nominal impact score is not simply the sum of the impacts of the services listed in the streamlined SRI catalogue. It is highly likely that due to local and site-specific context some domains and services are either not relevant, not applicable, or not desirable. The SRI methodology accommodates this by performing a triage process to identify the relevant services for a specific building.

The result of the smart-ready services assessment is translated into one overall SRI score and 3 sub-scores for the main functionality domains. Figure 2 depicts the SRI scores calculated at different levels.

	Overall SRI score (%) + SRI class							
	%		%				%	
	Optimise energy efficiency and overall in-use performance		Adapt its operation to the needs of the occupant				Adapt to signals from the grid (energy flexibility)	
	%	%	%	%	%	%	%	
	Energy efficiency	Maintenance and fault prediction	Comfort	Convenience	Health, well-being and accessibility	Information to occupants	Energy flexibility and storage	
Heating	%	%	%	%	%	%	%	%
Cooling	%	%	%	%	%	%	%	%
Domestic hot water	%	%	%	%	%	%	%	%
Ventilation	%	%	%	%	%	%	%	%
Lighting	%	%	%	%	%	%	%	%
Dynamic building envelope	%	%	%	%	%	%	%	%
Electricity	%	%				%	%	%
Electric vehicle charging		%		%		%	%	%
Monitoring and control	%	%	%	%	%	%	%	%

Figure 2: SRI scores calculated at different levels

2.3 Key Performance Indicators in EXCESS

This chapter presents the most relevant KPIs for the areas that are considered in the EXCESS project: energy related, economic, social and technical aspects. It first explains the perspectives where the report is limited, giving boundaries for the report. Section 2.3.1 focuses on energy related KPIs including flexibility aspects, section 2.3.2 presents the economic KPIs, and section 2.3.3 presents the KPIs for social aspects, including indoor environmental quality related to energy use. The technology related KPIs are presented separately, in Chapter 2.4.

EXCESS KPIs include indicators in following categories:

- Energy Perspective (e.g. energy efficiency, RES integration, energy flexibility, CO_2 emissions' reduction, air quality)
- Economic Perspective (e.g. cost of technology and measurement, energy costs reduction, revenue streams from market transactions, business models viability, return-on-investment, payback period, net present value, global costs)
- Social Perspective (e.g. users engagement, user acceptance, comfort and indoor environmental quality, energy security of supply, number of new jobs created, data security and privacy)
- Technology Perspective (e.g. system interoperability, conformance with standards, ICT solutions performance, compliance of functionality to the user requirements)

2.3.1 Energy Perspective

Of the potential energy related KPIs listed above - energy efficiency, RES integration, energy flexibility, CO_2 emissions' reduction, air quality - the last one is mainly relevant only in case of burning biofuels on site to reach the positive level. In the demo cases, only the original installation in Belgium includes a gas-burner, and even that will be deinstalled during the project. Therefore, this KPI is not highly relevant for EXCESS. The energy and RES related KPIs from different available sources are given in Table 2.

Table 2. The energy and RES related KPIs.

Indicator title	Unit	Definition	Source
Net primary energy demand	kWh/m^{2}year	Annual energy demand for HVAC minus RES production in terms of net primary energy and divided by useful floor area in m^2	EU 2012/C 115/01
Reduction in annual final energy consumption	% in kWh	Percentage change in annual final energy consumption due to the project for all uses and forms of energy	Huovila et al. 2017 (CITYkeys, adopted from Eurbanlab; Concerto; CIVIS; DGNB)
Increase in local renewable energy production	% in kWh	Percentage increase in the share of local renewable energy due to the project	Huovila et al. 2017 (CITYkeys, adopted from Eurbanlab; Eco-Districts, Concerto; LEED: CIVIS; IDEAS)
Annual net primary energy balance	% in kWh	Balance between the imported energy to the building and the exported energy to the grid	Belleri et. al. 2023
Self-generation (load cover factor)	% in kWh	Ratio between RES electricity used onsite and total electricity demand	Salom et. al. 2021
Self-consumption (supply cover factor)	% in kWh	Ratio between RES electricity used onsite and total RES production	Salom et. al. 2021
Change in total cumulative energy demand	% in kWh	Total (including fossil, renewable and other sources) cumulative energy demand during the life-cycle of the demo site in comparison to a reference case	VDI – The Association of German Engineers. 2012.
Greenhouse gas (GHG) emissions reduction	in % tonnes	The reduction of GHG is achieved by comparing to a case with no local renewable generation (in % tonnes). The volume of CO_2 emissions is based on the generation mix of the country for each demo site.	SCIS & Huovila et al. 2017 (CITYkeys, adopted from Eurbanlab; CIVIS; Concerto; 2 Decide; DGNB)

Flexibility indicators

EXCESS acknowledges three levels of flexibility, the building and district level, the grid level, and the market level. The building and district level flexibilities are often characterized by load matching indicators, while the grid level indicators are often describing how well the building utilises the available grid connections for minimizing the interaction with grid and avoiding grid congestions.

The flexibility of the building, energy system and markets have several definitions, depending on the context the word flexibility is used. IEA Annex 67 Energy Flexible Buildings (Pernetti et al 2017) defined: Energy Flexibility of a building is the ability to manage its demand and generation according to local climate conditions, user needs and grid requirements. The position paper presents the view of Annex 67 how to characterize and exploit energy flexibility of buildings.

In a review of building flexibility indicators Farulla et al (2021) recognised 16 definitions for flexibility in this context. The KPIs were classified according to the building and grid perspective. In building perspective there are three types of flexibility indicators:

- Load matching indicators showing the amount on-site generation compared to building energy demand (in EXCESS, this is included in the energy and RES related indicators)
- Grid interaction indicators describing how well the building utilises the grid connections, quantifying energy exchange between building and grid
- Energy flexibility indicators expressing how much energy or power can be shifted as response to external signals

H2020 project syn.ikia has developed a methodological framework for plus energy buildings and neighbourhoods considering also flexibility aspects. The flexibility indicators reported by syn.ikia (Salom 2021) are placed under the categories “Energy and environmental performance” and “Smartness and flexibility”. Regarding smartness, syn.ikia has chosen three aspects of Smartness Readiness Indicators (SRIs): adapt in response to the needs of the occupants and users, facilitate the maintenance and operation process, adapt in response to (price) signals from the grid; one impact criteria is “Flexibility for the grid and storage”

As an example of the ways to evaluate the functionality of storage and the flexibility provided by different storage applications or demand response, relevant examples can be found from STORY project, which tested several different storage technologies and applications (Kalms et al 2020). In STORY project, the focus was on the added value that storage could bring to the energy system. The approach was based on case studies, each of which had individual use cases or different goals that were targeted at the storage implementation. The success of the use cases was evaluated with technical, economic and environmental KPIs. In addition to the general KPIs, each demo had specific goals, the achievement of which were evaluated with demo specific KPIs. The detailed calculation and evaluation methods are described in a deliverable edited by Kalms et al (2020), including the results of the measurements and evaluation of the demonstrations of STORY project. The general technical KPIs included the following, some of which are also relevant for PEBs:

- Increased RES use
- Increased self-consumption
- Peak-to-average demand ratio
- Relative peak power change
- Grid losses change
- Grid energy consumption change
- Current and voltage total harmonic distortion change
- Voltage deviation change
- Storage capacity factor
- Storage efficiency
- Device availability

The KPIs relevant for flexibility from different sources are presented in Table 3. In internal discussions of the EXCESS team, some indicators seemed to be missing, and these are added in the table.

Table 3. Potential flexibility KPIs for EXCESS (based on Farulla et al 2021, Salom 2021, Kalms et al 2020, and EXCESS internal discussions).

Category	Indicator title	Definition
Load matching KPIs	Self generation (load cover factor)	Ratio between RES electricity used onsite and total electricity demand
	Self consumption (supply cover factor)	Ratio between RES electricity used onsite and total RES production
	Energy autonomy	Time share during which the entire local load can be covered by on-side generation
	Mismatch compensation factor	Capacity of local energy generation for which the annual net exported energy is zero divided by the capacity of the same system for which the economic value of annual import and export of electricity is the same
	On-site energy ratio	Ratio between energy supply from local renewable sources and energy demand
	Loss of load probability	Time share during which the building energy demand is not covered by the on-site energy generation
Grid interaction KPIs	Minimizing Grid interaction consumption	Balance of grid injection and off-take
	Peaks above limit	Percentage of time during that net exported energy exceeds a certain limit
	Connection capacity credit	Percentage of grid connection capacity that could be saved compared to a reference case
	No grid interaction probability	Probability that the building is acting autonomously of the grid
	One percent peak power	Mean power of the one percent highest quarter hourly peaks
	Absolute grid support coefficient	A measure of how a consumer's electricity consumption profile matches the availability of electricity assessed using a grid bases reference quantity
	Relative grid support coefficient	A measure of how a consumer's electricity consumption profile matches the availability of electricity assessed using a grid bases reference quantity
	Peak delivered/ peak exported power	Extreme value of net duration curve – Maximum negative/positive power peak value
Energy flexibility KPIs	Available structure storage capacity	Amount of heat can be added to the thermal mass of a building in the time frame of an active demand response event, without jeopardizing thermal comfort
	Flexibility factor	Ability to shift energy use from periods with high energy prices to periods with low energy prices
	Cost avoided flexibility factor	Ability to shift the heat pump electric load from peak to off-peak hours in terms of electricity price

	Volume shifted flexibility factor	Ability to shift the heat pump electric load from peak to off-peak hours in terms of energy shifted compared to a reference profile
	Storage efficiency	Fraction of heat that can be stored in the timeframe of an active demand response event to be used subsequently aiming to reduce the heating power needed
	Available electrical energy flexibility efficiency	It shows the storage efficiency based on whether upward or downward flexibility is provided
	Flexible energy efficiency	It measures of how much energy was shifted taking into account the rebound effect
	Flexibility index	Defined as the savings due to utilising energy flexibility for a given price-signal

2.3.2 Economic perspective

The economic perspective includes indicators on:

- cost of technology and measurement
- energy costs or cost reduction compared to reference case
- revenue streams from market transactions
- business models viability
- return-on-investment
- net present value
- payback period
- global costs
- levelized cost of energy
- nZEB Cost Comparison

Table 4 presents the relevant economic indicators for positive energy buildings and gives a detailed description of the indicators. In the practical evaluation phase, some decision has to be taken: scope of the evaluation giving the boundaries for the analysis (system boundary) and decision if the analysis includes full costs or costs compared to reference case, e.g. additional costs of better energy efficiency compared to traditional case. The business model viability can be assessed by using the information from several economic indicators, such as the return-on-investment and payback time, but also some of the social indicators are relevant for this (e.g. people reached, user acceptance).

Table 4. Economic indicators for positive energy buildings.

Name	Description
CAPEX - CAPital Expenditures Demos	Summing up all upfront investment required to purchase, manufacture, install and put in operation the required equipment and activate service operation (excluding ICT)
OPEX - OPerational EXpenditures	Summing up all annual recurrent costs, required to operate and maintain the installed equipment.
Increase in revenue of the flexibility service provider	In a context of aggregation of various assets, the use of an optimizer will help maximize the revenue of the aggregator when providing multi-services by taking account generation forecasts, market prices, service remunerations, etc. This will encourage new players to participate in ancillary service markets.
Reduced overall cost	Intended to give a statement about the overall costs when R&I solutions are applied, compared to the Business-as-Usual (BaU) methodology.
Energy cost	The indicator will measure the energy cost that depends on the purchased energy from the grid as well as the electricity price per kWh.
Energy savings	This indicator is usually used for project evaluation (where suppliers are involved), and for consumer behaviour change (for consumers). It will measure the difference between measured and reference consumption data, evaluated within a predefined period of time.
IRR	The indicator internal rate of return, IRR, is used to estimate the profitability of potential investments. IRR is a discount rate that makes the net present value (NPV) of all cash flows equal to zero in a discounted cash flow analysis.
NPV	Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. If the NPV of an investment is >0, the investment is profitable otherwise the investment should be rejected.
Pay-back Time	Pay-back Time is the period of time (years) required to recover the funds expended in an investment. The payback period is a method of analysis with limitations for its use, because it does not account for the time value of money, but it is easy to use
Global costs	Global costs are used for cost-optimal analyses as defined in EU 2012/C 115/01. The global cost calculation considers all initial investment costs and the net present value of operation and maintenance costs for a predefined calculation period.
Levelized cost of energy	average minimum price at which the electricity generated by the asset is required to be sold in order to offset the total costs of production over its lifetime.
nZEB Cost Comparison (%)	The nZEB Cost Comparison is computed as the ratio between the total cost of the respective investment and its nZEB alternative. The calculation period should cover the expected lifetime of the SPEN and the reference, e.g., 50 years.
Employment	The number of jobs created through the whole value chain

The economic analysis is very demanding in the situation where the uncertainty of the prices and discount rates in time scale is very big. During EXCESS project the prices of materials and components have increased and there has been lack of materials due to war in Ukraine. This also causing delays in supply chain, which is causing indirect economic losses and leads to higher prices.

2.3.3 Social perspective

In accordance with the original plan, KPIs from a social perspective should include at least the following aspects:

- user engagement
- user acceptance
- comfort and indoor environmental quality
- energy security of supply
- number of new jobs created
- data security and privacy
- ethics

Evidence shows that more social cohesion leads to more altruistic behaviour and more willingness to take action together with more trust in each other (Gullstom & Kort 2019). Taufik & Dagevos (2021) use a Corporate Social Responsibility (CSR) perspective to examine public acceptance of industrial activities. The findings indicate that to gain public acceptance and prevent scepticism, industries need to explore ways that assure citizens that these industrial activities ultimately are an extension of core moral, societal industry values. This strengthens citizens' values-driven attributions, and in turn creates public trust and minimalizes greenwashing perceptions. This becomes even more essential when dealing with citizens who believe they are relatively knowledgeable on the topic of renewable energy technologies. Naturally, people who are more engaged with environmental issues and those who are inclined to express public preferences will be in favour of renewable technologies more than the others (Ek 2005). Therefore, it is important to engage the users and other stakeholders in the building project in early phases to e.g. increase the user acceptance for the solutions.

The long list of social indicators has been collected in tables acting as checklist when selecting the case or project specific indicators. Indicators for user engagement and other social indicators are presented in Table 5 and Table 6.

Table 5. Indicators for participation, involvement and awareness

Indicator title	Indicator unit	Definition	Source
People reached	% of people	Percentage of people in the target group that have been reached and/or are activated by the project	Huovila et al. 2017 (CITYkeys)
Increased participation of vulnerable groups	Likert	The extent to which project has led to an increased participation of groups that are not well represented in the society	Huovila et al. 2017 (CITYkeys)
Local community involvement in planning phase	Likert scale	The extent to which residents/ users have been involved in the planning process	Huovila et al. 2017 (CITYkeys, adopted from Eurbanlab; Green Digital Charter)
Local community involvement in implementation phase	Likert scale	The extent to which residents/ users have been involved in the implementation process	Huovila et al. 2017 (CITYkeys)

Table 6. Indicators for social aspects and acceptance (based on Angelokoglou et al 2020, Salom 2021, Huovila et al. 2017 CITYkeys, adopted from Eurbanlab, and EXCESS internal discussions).

Indicator title	Indicator unit	Definition
Affordability	Likert scale	Can all people who want to, afford to live in a PEB?
Health and safety	Qualitative description	Consumers' rights to be protected against products and services that may be hazardous to health or life (ISO 26000, 2008), this includes: • information about the technology being used • possibility to place feedback, complaints • management measures to improve feedback mechanisms
User acceptance	Likert scale	User acceptance is the willingness of users to use different apps and tools
Ease of use for end users of the solution	Likert scale	The extent to which the solution is perceived as difficult to understand and use for potential end-users
Ease of use for professional stakeholders	Likert scale	The extent to which the innovation is perceived as difficult to understand, implement and use for professional users of the solution
Community engagement	Likert scale	Whether an organization includes community stakeholders in relevant decision-making processes. It also considers the extent to which the organization engages with the community, in general. (Maybe also important for energy communities?)
Visibility of Results	Likert scale	The extent to which the results of the project are visible to external actors
Safe and Healthy Living Conditions	Yes or No	Are there any potential health and safety impacts of the operations to surrounding communities?
Local employment	% of people hired locally	Local hiring preferences provide important income and training opportunities to community members. Organizations that develop relationships with locally based suppliers will further encourage local employment and development. Organizations also may encourage local community development by training local employees in technical and transferable skills.
Energy Poverty		Change of percentage of energy-poor households.

<u>Indoor environmental quality (IEQ)</u>

The indoor environmental quality related indicators are described limiting the content in things that can or may be affected by the PEB concept (mainly energy efficiency and renewable choices). These include both comfort and indoor air quality.

Comfort

Comfort in building context is usually defined as thermal, acoustic and visual comfort. Nowadays even ergonomics is sometimes included in indoor environmental quality. All these comfort aspects are affected both by physical, psychological and social factors. Therefore, their measurement only by physical determinants may not assure optimal comfort, but rather ensure that the best possible environment is provided. Best comfort usually also requires that the building user is given an opportunity to affect the physical variables (temperature, lighting level, noise level, etc).

Thermal comfort

Thermal comfort is the ''*condition of mind that expresses satisfaction with the thermal environment*" (ASHRAE 2003). Thermal comfort is measured as Thermal sensation votes or, in case the actual votes are not available, calculated by Predicted Mean Vote (PMV) or Predicted Percentage of Dissatisfied (PPD) indicators. The limits for these are presented in ASHRAE Standard for Thermal Environmental Conditions for Human Occupancy (see Table 7, ASHRAE 2003).

Table 7. Three classes of acceptable thermal environment for general comfort according to ASHRAE standard 55 P (2003).

Comfort Class	PPD	PMV rate
A	<6	-0.2<PMV<+0.2
B	<10	-0.5<PMV<+0.5
C	<15	-0.7<PMV<+0.7

According to the ASHRAE Standard, PMV and PPD values are calculated based on six primary factors that must be addressed when defining conditions for thermal comfort. There are also other, secondary factors that affect comfort in some circumstances. The six primary factors are:

1) Metabolic rate
2) Clothing insulation
3) Air temperature
4) Radiant temperature
5) Air speed
6) Humidity

In building design, assumptions can be made for some of these, like metabolic rate and clothing insulation, based on the building use (residential/office/other). In the PMV method, "*the comfort zone is defined in terms of a range of operative temperatures that provides acceptable thermal environmental conditions or in terms of the combinations of air temperature and mean radiant temperature that people find thermally acceptable*". (ASHRAE 2003) Usually in residential buildings, the average value of the air temperature and radiant temperature can be used as the operative temperature[2], and often it is approximated by the air temperature. In a high quality building the air speed and humidity should be controlled by BMS and kept inside the design values, although they can occasionally be outside these design values e.g. due to the activities by building users (opening windows, cooking, using own separate fans). ASHRAE Standard (ASHRAE 2003) gives detailed instructions for the measurement of the different variables.

[2] It can be used for cases where occupants are engaged in near sedentary physical activity (with metabolic rates between 1.0 met and 1.3 met), not in direct sunlight, and not exposed to air velocities greater than 0.20 m/s (ASHRAE 2003).

Acoustic comfort

Acoustic comfort is usually referred to as "*the perceived state of well-being and satisfaction with the acoustical conditions in an environment*" (e.g. Azar et al. 2020, Vardaxis et al 2018, Rindel 2002). It can be affected by two main types of noise in buildings: (i) structure-borne (impact) noise that is created by physical impact or vibration against a building element, and (ii) airborne noise that is transmitted through the air (Hopkins 2007). In PEB, these can be affected e.g. by improved insulation level of the structures and windows (improving the comfort) or in case of renewables, the wind turbines or hydro-power plant (potentially reducing the comfort).

The sound pressure level is one of the main acoustical factors that affect comfort. Maximum sound pressure level (L_{max}) is typically used when predicting comfort with impact noise, while the relevant indicator for airborne noise is equivalent sound pressure level over a given period of time (L_{eq}) (Jeon et al 2010, Ouis 2002). Other acoustical factors that impact acoustic comfort are: (i) frequency of the noise, (ii) noise source, (iii) duration of noise, and (iv) its variation with time (Guski 1999, Burns 1973).

Visual comfort

The European standard EN 12665 defines visual comfort as ''*a subjective condition of visual well-being induced by the visual environment*". (CEN 2007)

Visual comfort is still a developing field, and no common standards exist for defining or measuring it. Visual comfort is usually defined through a set of criteria based on the level of light in a room, the balance of contrasts, the colour 'temperature' and the absence or presence of glare. This may include also aspects like quality and access to views from inside the building or the quality of the surrounding space.

Recommendations for (minimum) limits of illumination levels are generally given depending on the task performed, and usually only for other than residential buildings. E.g. ILO Encyclopaedia (Hernández 2011) lists the following as prerequisites that the illumination system must fulfil in order to provide the conditions necessary for visual comfort (related to working conditions):

- uniform illumination
- optimal luminance
- no glare
- adequate contrast conditions
- correct colours
- absence of stroboscopic effect or intermittent light.

Related to the PEB concept, the visual comfort might be affected by glare from the PV-panels or wind turbines (reducing) or by the improved visuals of the façade by the façade elements (in Austrian case) or façade integrated PV panels (in Finnish case). These are most often visible only from outside the building, and not affecting much the indoor environmental quality.

Indoor air quality (IAQ)

Indoor environment quality (IEQ) also includes the indoor air quality (IAQ), which has several assessment methods. IAQ has no universal or standard definition, but in general it is related to pollutants (e.g., biological, chemical, and physical) within indoor environments that can affect the health of occupants (Steinemann et al 2017). The US Environmental Protection Agency (2016) gives the following definition: "*Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.*"

The time-weighted concentration thresholds of air contaminants are the key information needed to evaluate if adequate IAQ levels are reached. From the different indoor air pollutants, eight groups of substances are the most frequently addressed contaminants: carbon dioxide (CO_2), nitrogen dioxide (NO_2), formaldehyde (HCHO), carbon monoxide (CO), sulphur dioxide (SO_2), particulate matter in sizes up to 2.5 and 10 lm (PM2.5 and PM10, respectively), total volatile organic compounds (TVOCs), and Ozone (O_3), (Azar et al 2020). In addition, WHO lists e.g. benzene, naphthalene, polycyclic aromatic hydrocarbons (especially benzo[a]pyrene), radon, trichloroethylene and tetrachloroethylene as substances that are known for their hazardousness to health.

In residential buildings, the IAQ is usually not measured extensively, usually one-time measurement of levels of radon in the air and potential CO-concentration, moisture and smoke detectors are considered adequate. An adequate air exchange rate combined with air filtering is usually considered sufficient methods to keep the levels of concentration of other pollutants low enough.

EXCESS measurements related to IEQ

For the assessment of IEQ, EXCESS will measure:

- Thermal preferences (comfort temperature range) per day of week, per month, per time of day
- Visual preferences (comfort Illumination range) per day of week, per month, per time of day
- Thermal comfort distribution
- Visual comfort distribution

For this, four types of data are required:

- historic values of indoor environmental conditions, such as temperature, humidity, illuminance
- historic log of human actions and events, like turning on/off a HVAC system, switching on/off the lights, setting a temperature setpoint, etc.
- temporal information for the datetime of the requested forecast (which is directly available)
- weather forecast in order to extract the required features for the estimations to be made.

The data is being collected in the EXCESS demos via sensors in the apartments.

<u>Ethics aspects</u>

To include ethical aspects when introducing new technologies is a must. These include in the case of EXCESS mainly:

- how we treat people and communities and
- how we use and manage data we gain when using new technologies.

EXCESS involves the carrying out of household, building and DER data collection in the four demo sites in Spain, Finland, Belgium and Austria. For this reason, human participants will be involved in certain aspects of the project and data will be collected. This was and will be done in full compliance of the main legislation and more specifically Directive 2016/679/ EC (also known as General Data Protection Regulation, “GDPR”) on Data Protection and Privacy which is currently in force in the Member States where the demonstrations will be carried out.

Also, when testing and installing the new technologies, tools and apps, the security of personal data, confidentially and the protection from data breach must be ensured at all times. It also must be ensured that equipment will be installed with minimum intrusion on the occupants' daily life and within the provisions of the respective legal provisions of each country.

The ethical guidelines (and indicators) for EXCESS can be furthermore built on six ethical principles based on previous studies (Ikonen et al 2009) listed in Table 7 in addition to the IPR principle. They are all assessed from qualitative descriptions.

Table 7. Indicators for ethics related aspects.

KPI	Description
Privacy	An individual shall be able to control access to his/her personal information and to protect his/her own space.
Autonomy	An individual has the right to decide how and for what purposes (s)he is using the technology.
Integrity and dignity	Individuals shall be respected, and technical solutions shall not violate their dignity as human beings.
Reliability	Technical solutions shall be sufficiently reliable for the purposes to that they are being used for. Technology shall not threaten users' physical or mental health.
E-inclusion	Services should be accessible to all user groups, regardless of physical or intellectual/developmental disabilities.
Benefit society	Society shall make use of the technology, so that it increases quality of life and does no,t cause harm to anyone.
Respect of Intellectual Property Rights	Organization´s actions must safeguard and value the creators and other producers of intellectual goods and services. The legal rights dealing with the intellectual property entail intellectual activities in the industrial, scientific, literary, and artistic fields.

Social acceptance of the EXCESS solutions may be investigated and strengthened, while using these guidelines and indicators both in the development and monitoring of the project work.

2.4 Technical subsystem indicators

According to the initial ideas, the technology perspective KPIs should at least include the following:

- system interoperability
- conformance with standards
- ICT solutions performance
- compliance of functionality to the user requirements

The different technology components have interactions with each other's, which can be explained by the example of system analysis of PVT as part of energy system (Figure 3). Each component can be characterised by own performance indicators, and in some cases by the indicators showing the interactions at the same time, e.g. self-consumption of PV electricity production by heat pump.

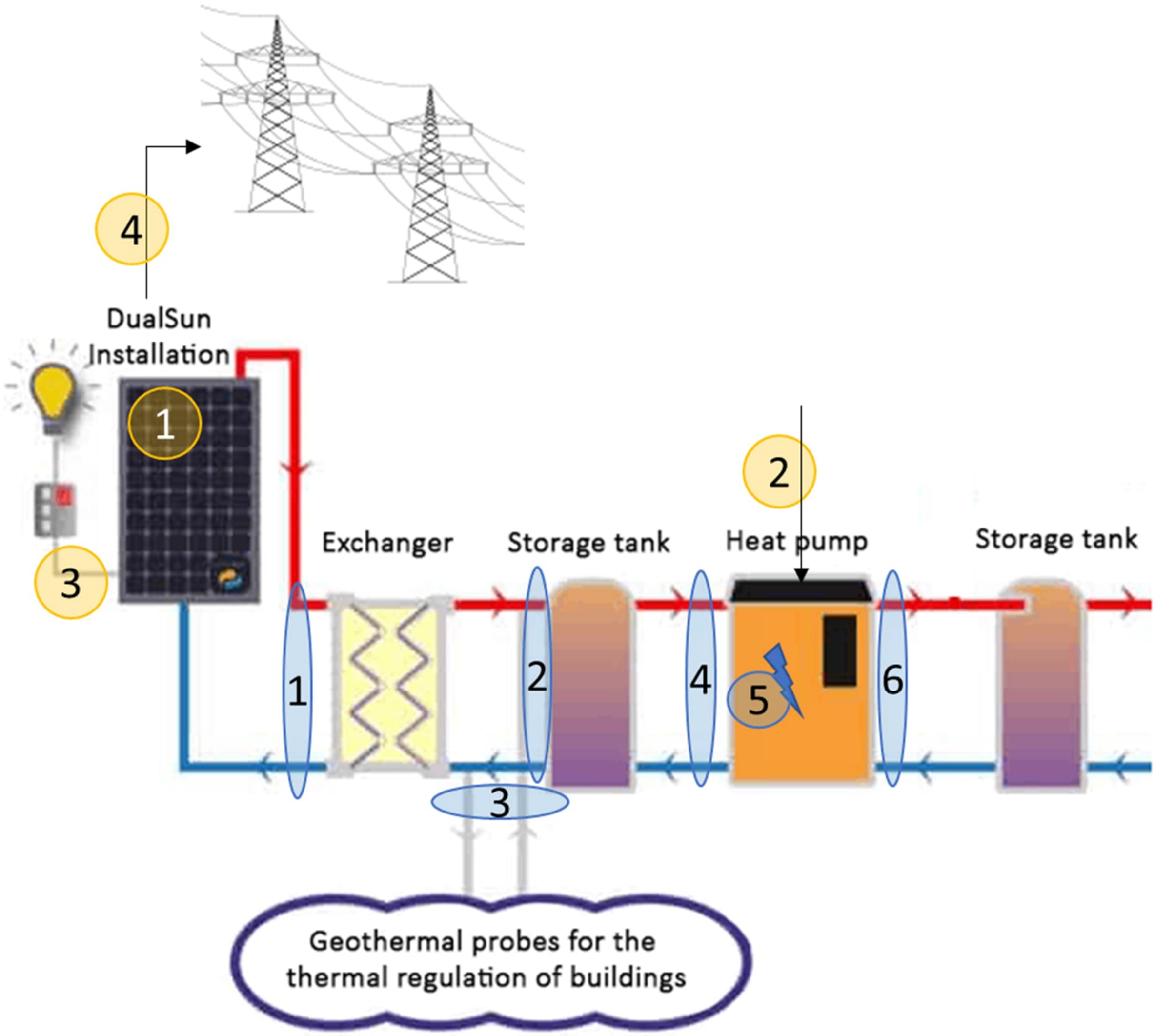

Figure 3. PVT as part of energy system.

2.4.1 Solar thermal PVT panels

Table 8 shows the performance indicators of PVTs as part of energy system in Figure 3.

Table 8. KPI's relevant for PVTs as part of energy system.

Photovoltaic		
1	PV total production	«Smart» inverter or electrical meter of the PV production (by step <15mn)
2	Self-consumption by the HP	Measurement of the HP electrical consumption (by step <15mn)
3	Self-consumption by other appliances	Measurement of the global electrical consumption (by step <15mn)
4	PV to grid	(Official) measurement of the delivery to the grid

Thermal		
1	Solar heat total production	Inlet/Outlet temperature + flowrate
2	Solar heat directly to the HP (or to the cold storage if any)	Inlet/Outlet temperature + flowrate
3	Solar heat for boreholes regeneration	Inlet/Outlet temperature + flowrate
4	Heat delivered to the HP	Inlet/Outlet temperature + flowrate
5	Additional heating (electrical or gas additional heating if any)	Electrical meter (or communication with the HP)
6	Heat delivered to the building	Inlet/Outlet temperature + flowrate
7	Pumps and auxiliary (for heating) consumption	Electrical meter

These KPIs have been fully described IEA Task 60 about PVT systems (https://task60.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task60-D1-Key-Performance-Indicators.pdf) and the methodology has been used in examples in this task (https://task60.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task60-2020-System-Evaluation.pdf).

As the level of the modules, PVT is a hybrid module, panels performances need to be certified according to European standards IEC (for the photovoltaic part) and Solar Keymark (for the thermal part) in an accredited certified laboratory.

- IEC 61215 [PV part in a PVT]:
  - performance tests (Maximum power determination; Measurement of temperature coefficients; Performance at STC; Performance at low irradiance);
  - security tests (Insulation test; Wet leakage current test) and
  - ageing testing (Outdoor exposure test; Hot-spot endurance test; UV preconditioning test; Thermal cycling test; Humidity-freeze test; Damp heat test; Static mechanical load test; Hail test; Bypass diode testing; Cyclic / dynamic mechanical load test; Potential induced degradation test; Bending test)
- IEC 61730 [PV part in a PVT]:
  - performance tests (Performance at STC; Maximum power determination; Bypass diode functionality test);
  - Security (Insulation thickness test; Sharp edge test; Cut susceptibility test; Continuity test of equipotential bonding; Impulse voltage test; Insulation test; Wet leakage current test; Ignitability test; Reverse current overload test; Module breakage test; Screw connections test; Robustness of terminations test);

  - Ageing (Durability of markings; Hot-spot endurance test; Bypass diode thermal test; Static mechanical load test; Peel test; Lap shear strength test; Materials creep test; Thermal cycling test; Humidity freeze test; Damp heat test; UV test MST; Cold conditioning; Dry heat conditioning)
- ISO 9806 [Thermal part in a PVT]:
  - Performance (Thermal Performance Testing; Leakage Rate Test; Effective Thermal Capacity and Time Constant; Determination of the Incident Angle Modifier; Determination of Pressure Drop);
  - Security (Internal Pressure Test; Standard Stagnation Temperature; External Thermal Shock Test; Internal Thermal Shock Test);
  - Ageing (Exposure and Half-Exposure Test; Rain Penetration Test; Freeze Resistance Test; Mechanical Load Test; Impact Resistance Test)

2.4.2 Geothermal system

The most relevant KPIs for the ground heat exchangers (GHE) that are considered in the EXCESS project and demo case in Finland are reviewed here. Finnish EXCESS positive energy building is located at Kalasatama district, in the city of Helsinki.

The hybrid geothermal energy system at Kalasatama building is a combination of semi-deep geothermal boreholes, heat pumps, solar photovoltaic panels and combined PV and thermal panels producing electricity and heat.

Geothermal energy has a unique position among the renewable energy resources. In fact, we live right on top of the most affordable, sustainable and comfortable energy source on earth thanks to earth's relatively constant underground temperature. Therefore, ground can be used as a heat source during the winter and as a heat sink during the summer to capture or dissipate heat from or into the rock.

Usually there are two ways of upscaling ground source heat pump systems installations, either by increasing the number of boreholes or by increasing the depths of the boreholes. Whereas the first alternative needs additional surface area, the deeper boreholes (beyond 600 m), which are more challenging than the conventional boreholes, can be applied when there is a lack of space, e.g., in dense living areas. The challenge of geothermal energy industry is to develop the geothermal systems integrated with other renewable energy sources, towards hybrid energy systems, and develop deeper borehole solutions requiring less space in dense built areas.

General KPIs for the ground heat exchangers have been fully described in IEA Annex27. IEA ECES (2020), "Quality Management in Design, Construction and Operation of Borehole Systems", [Reuss et al., ZAE Bayern], IEA Technology Collaboration Programme on Energy Conservation through Energy Storage (IEA ECES), 2020.

MuoviTech as technology provider for the ground heat exchangers in the Finnish demo case has activity contributed to development of the Annex 27.

– Material: PE pipes for pressure applications should be classified by minimum required strength (MRS) based on the international standard ISO 9080. According to ISO 9080 the minimum MRS) at 20°C and 50 years for a pipe with SDR 11 is 10 MPa.

- Thermal degradation, pressure class and other dimensions of the pipes should be according to the standard EN 12201.
- Energy performance: As soon as all energy systems are installed and integrated the monitoring of the energy performance will be monitored. The energy performance of GHE in long term monitoring should be according to IEA HTP Annex 52, long term performance measurement of GSHP Systems serving commercial, institutional and multi-family buildings (https://heatpumpingtechnologies.org/annex52/)
- Thermal response test should be done after the installation of the GHE and it should be according to IEA HTP Annex 21 (https://iea-es.org/annex-21/)

2.4.3 Heat pumps

The low temperature heat collected from the ground is heated up by heat pumps. The heat source for heat pumps can also be air or water, but in EXCESS, the main applications are ground source heat pumps (in Finnish and Belgian cases). In Spanish demo case, an aerothermal heat pump is applied. The description of operation and KPIs for a heat pump system below is provided by Gebwell (https://gebwell.fi/en/ground-source-heat/).

In a ground source heat pump system, a liquid solution circulates in the piping and is warmed up by the heat which has accumulated in the surrounding earth. In the heat pump's evaporator, energy is transferred from the liquid solution to a refrigerant, cooling the solution approximately three degrees. The temperature and pressure of the refrigerant is increased to a higher level by using a compressor. In the condenser the energy is transferred from the refrigerant to the water circulating in the (underfloor or radiator) heating system and to domestic hot water heating in the energy accumulator.

The best efficiency from a pump is achieved when heat distribution is carried out using underfloor heating or some other low-temperature method. In underfloor heating, the temperature of supply water is lower (28–40 ◦C) than in radiator heating, for example, where the supply water temperature is usually between 35–60 ◦C. Radiator heating does not rule out ground source heating, as e.g. Gebwell's ground source heat pumps can reliably produce water with a temperature of 60 ◦C.

The most relevant KPIs for a heat pump are Coefficient Of Performance (COP) and Seasonal Coefficient Of Performance (SCOP).

The COP of the heat pump is usually referred to as efficiency. COP indicates the ratio of the consumed and produced energy, how efficiently the consumed electrical energy can be converted into heat (or cooling) energy.

Formula: COP = The heat energy received from a ground source heat pump (kW)/the electrical energy consumed by a ground source heat pump (kW) For example, COP 5 means that a 1 kW input power produces 5 kW of heat energy. The higher the figure, the more energy-efficient the device is.

The SFS-EN 14511 standard published by Suomen Standardoimisliitto sets the principles according to which the energy calculation of heat pumps intended for heating or cooling room spaces is made. The coefficient of performance, or COP, of heating devices is calculated in accordance with this standard. COP rating is normally defined by conducting the measurements at a temperature of +7 degrees. Because of this, COP alone will not always yield reliable information about the functionality of a heating device, for example, in sub-zero temperatures. When comparing COP ratings, it is worth confirming the standard and conditions used in the calculation. The previously used SFS-EN 255 standard gives a better COP value than calculations performed using the official SFS-EN 14511 standard.

SCOP indicates the efficiency of the ground source heat pump better than COP because it takes into account the variations between different heating periods. SCOP is calculated for four different heating periods because the temperature intervals applied to the calculation, the basic temperature measurements and the dimensioning loads are seasonal. In addition, geographical climate zones are taken into account when calculating the heat coefficients of ground source heat pumps. In Northern Europe, the calculation of a heating period heat coefficient is based on the climate conditions of Helsinki.

2.4.4 Multifunctional facade

For the EXCESS demo building in Austria the objective is the improvement of the thermal quality of the building envelope and the implementation of an innovative energy production and energy supply system. Therefore, a prefabricated multifunctional facade element to facilitate the renovation of existing buildings was developed. This facade element includes integrated energy producing active elements (PV), insulation and hydraulic activation elements for the use on existing facades as a heat/cold storage and heat dissipation system. In conjunction with the defined energy supply concept in the Austrian demo case, the overall concept transforms the exterior wall into a cost-effective energy storage as well as an interesting element to increase the energy flexibility by storing surplus electricity in the activated element.

<u>Key Performance Indicators for Multifunctional facades</u>

Economic Indicators

The proposed system not only enables the integration of window and various HVAC technologies but should also lead to cost reduction in building renovation. Economic savings are achieved in the use of materials, execution time and labour intensity.

The façade modules are completely prefabricated, so it has not been necessary to cut the cladding material, the insulation material and other facade components, as is the case in conventional façade renovations were window joints, corners and perimeter of the facade, are necessary to cut the components to adapt them to the geometry which produces waste of material. Regarding construction waste, as all the elements that make up the façade system (profiles, trims, anchors, insulation material, heating elements, etc.) are included in the active façade modules, not so much construction waste has been generated during assembly.

In the course of installing the prefabricated façade on the existing wall, a heating element is integrated at the same time. This leads to a considerable simplification of the renovation process, since on the one hand, outdated heating and delivery systems do not have to be expensively retrofitted, and on the other hand, the residents can remain in the building during the entire renovation process. This avoids additional renovation costs due to the relocation of residents.

A reduction in the execution time, labour and auxiliaries is expected thanks to the “plug and play” concept. The substructure of the system is as simple as for conventional facade systems but the prefabricated “plug and play” system allows for quick and easy assembly of the facade, and use of cranes instead of scaffolding. Altogether it should lead to a time reduction.

The aforementioned savings will be demonstrated in the demonstration building by comparing them with parameters of conventional renovation processes for ventilated façade systems.

Energy Production Indicators

The external finish will be customized so that active systems can be integrated. In the demo building the two building orientations (South and West façade) will be equipped with PV modules. With a target of having a plus energy building, a total of 136 panels in the south facade and 230 panels in the west façade of the building with 90◦ inclination with a total area of 520 m^2 were selected for this purpose. The expected PV production is approximately 62 MWh/a. The real electrical yield will be measured with electrical meters. Further PV related KPIs are self-consumption by the energy system for heating, cooling and self-consumption by other appliances as well surplus energy delivered to the grid and global electricity consumed.

Energy Active Façade Indicators

The determination of the HTC (Heat Transfer Coefficient) between the heating medium and the existing wall is an elementary step in the characterization of the active facades. In the real structure, the heat flow from the fluid in the pipes of the activation layer to the outer surface of the as-built wall is characterized by complex geometries and a variety of material properties. The use of a single coefficient for this situation allows the use of 1-dimensional mathematical models and simplified design calculations. The HTC can be determined either theoretically with high-resolution FEM simulations (e.g. with HTFlux) or by measurements. Since the geometry of the real contact situation between active layer and as-built wall is partly unknown, the use of an innovative measurement method is necessary here.

For this purpose, in the first step a 1-dimensional wall model of the facade is created with the simulation software IDA ICE. This model internally characterizes the active layer with an HTC value and is thus based on the simplified layer method.

For the evaluation of the multifunctional façade, the system is operated over several weeks under different test scenarios (heating up, cooling down, active cooling) and different framework conditions (room temperatures, ambient temperatures, etc.). The façade module including the active level as well as the concrete wall and the test rooms will be equipped with measurement technology for temperature and power measurement.

The measurement results serve on the one hand for the direct interpretation of the performance and on the other hand for the determination of characteristic key figures (e.g. HTC values) that describe the heat transfer of the active layer to the existing wall. For this purpose, the theoretical model will be compiled with the real measurement data and a parameter identification will be carried out.

Further KPIs for the façade elements are the total delivered heat and cold $\dot{Q}_h$ to the building measured with inlet- outlet temperatures and flow meter.

Energy Flexibility Indicators

To evaluate the flexibility potential of the active façade system, a series of Key Performance Indicators (KPIs) can be used. The structure storage capacity C_ADR represents the amount of additionally stored heat energy during an Active Demand Response signal (ADR) which could be a PV-production curve compared to the reference scenario (non ADR) over the duration t_ADR. With $\dot{Q}_h$ representing the heat flow provided by the heat supply system.

$$C_{ADR} = \int_0^{t_{ADR}} (\dot{Q}_{h,ADR} - \dot{Q}_{h,ref})dt$$

The building mass storage efficiency **η**_ADR builds onto the before introduced structure storage capacity C_ADR and describes how much of the stored heat energy can be regained effectively during the observation period. Unlike C_ADR which is only calculated during the time of an active ADR signal, η_ADR is highly dependent on how long the observation period is chosen. To get conclusive results the storage efficiency is calculated annually in this approach.

$$\eta_{ADR} = 1 - \frac{\int_0^{8760\,h} \dot{Q}dt}{\int_0^{tADR} \dot{Q}dt} = 1 - \frac{\int_0^{t\,h} \dot{Q}dt}{C_{ADR}}$$

The non-thermal grid interactive period is defined as the period of time during which the building/thermal zone does not need to be supplied with energy in the form of heating or cooling in order to maintain thermal comfort within a certain range.

3 Targets, KPIs and measurements in demo cases

The section describes the demo cases in four countries, case specific selected KPIs and the data, measurements and instrumentation needed for the calculation of KPIs. The pathway from single measurements towards KPIs and energy balance of the building showing the energy performance is explained.

3.1 Demo case in Finland

Finnish EXCESS positive energy building is located at Kalasatama district, in the city of Helsinki. The project is developing the concepts of positive energy houses. The project has two separate buildings including 145 apartments. The total floor area is almost one hectare. The plot is located in the centre of Helsinki, in the new fast developing area at Kalasatama close to sea. The city centre area is typically served with district heating network and buildings are mixture of residential and commercial buildings. Demo building is similar, having residential apartments, commercial spaces and restaurant at the first floor.

3.1.1 Targets and goals of the Finnish demo case

The project is developing new type of housing solutions aiming at positive energy buildings, producing at least the same amount of energy than they are using, when looking at the yearly energy balance. The project at Kalasatama has two separate houses, one 8 floor and one 13 floor building. The lower one participates in EXCESS EU Horizon project and the higher one participates in HYBGEO Business Finland financed project. EXCESS demo demonstrates the performance of positive energy house at Kalasatama, and we expect PEBs and nearly zero energy buildings will become common practise in the future projects.

Kalasatama area is a perfect place to demonstrate PEBs: it is a part of City of Helsinki's Re-thinking Urban Housing programme, which aims to increase the quality and appeal of living in blocks of flats and integrate new personalised solutions into it. The programme provides developers with the opportunity to try new things and receive valuable guidance from city experts for the development efforts.

The key info of Finnish EXCESS demo building is presented in Figure 4 and Table 9.

Figure 4. EXCESS demo building in Kalasatama, Helsinki.

Table 9. Key figures of Finnish EXCESS demo building and energy system.

<u>Building:</u>	<u>Energy system:</u>
• 2 buildings, EXCESS demo in lower one • 2-13 floors • 145 apartments / 8254 h-m^2 • House AB (As Oy Aurinkoamppeeri) 52 apartments / 2814 h-m^2 • House CD (As Oy Geowatti) 93 apartments / 5440 h-m^2 • Apartments 26,5 – 100 m^2, average 57m^2 • Restaurant and 4 commercial spaces, 456 m^2 • parking for 56 cars, underground space • 2 shared cars, by shared car services • Spaces for bikes inside 234, outside 97 • Solar panels at facades and at roof • Challenging underground conditions, due to location in dense living area near harbour	• Deep boreholes 3-5x800m (drilling technology and heat exchangers collector) • 67 kW_{el} DualSun PVT panels, 315 m^2 • for multisource ground source heat pump with defrosting function • PVs at facades, 348 m^2 • Seasonal borehole storage. PVT heat surplus will be used to charge the ground during transitional months, while during summer the HP condenser using the PVT as thermal source will dump heat to the ground. • Multisource ground source heat pump system for deep boreholes with high COP for DHW with 2x500 litre and 2x300 litre short term tanks and remote heat pump monitoring, on-line commissioning and fault diagnostics. • Utilisation of the excess heat of exhaust ventilation • Smart control and optimisation

The design values for the energy efficiency of the Finnish demo building are presented in Table 10.

Table 10. Energy efficiency design values of the Finnish demo house.

Envelope	A (m^2)	U (W/m^2K)	UA (W/K)	share of heat losses
External walls	2075,4	0,16	327,9	29 %
Roof	643,7	0,09	59,9	5 %
Floor	643,6	0,14	89,5	8 %
Windows	849,5	0,60	510,5	45 %
Cold bridges			144,1	13%
Air leakage q50		1,0 $m^3/(h\ m^2)$		
Heated net area		4069 m^2		
Windows at facades	A (m^2)	U (W/m^2K)	g-value	
North	20,2	0,60	0,50	
North-East	15,1	0,60	0,50	
South-East	374,9	0,60	0,50	
South-West	116,3	0,60	0,48	
North-West	322,8	0,60	0,48	
Ventilation system		mechanical supply and exhaust with heat recovery		
	Air flow rate supply / exhaust (m^3/s) / (m^3/s)	SFP ($kW/(m^3/s)$)	Heat recovery efficiency	Defrosting limit (°C)
Main ventilation machines	2,75 / 2,75	1,52	83 %	-10
Heating system		Geothermal heat, floor heating		

The planned energy balance (in electricity) of the Finnish demo house is presented in Figure 5. The electricity needed for heating the spaces, ventilation, cooling and domestic hot water is 27,1 kWh/m^2a and own production with PV panels and PVT panels is 23,9 kWh/m^2a. The gap between is 14% of the PV and PVT production. For zero balance 60-150 m^2 more panels would be needed, depending on the orientation of the panels, or remarkable improvement of the efficiency of the panels. The increase of the area of panels is difficult to do in practise, due to limited space in facades ad roof and shading caused by the buildings nearby.

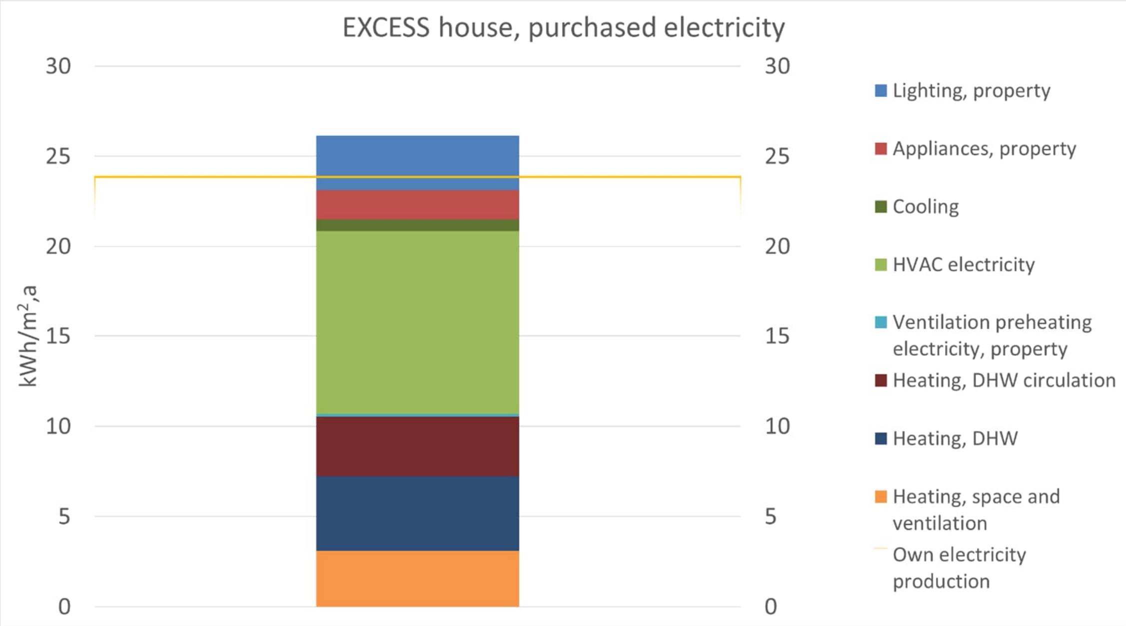

Figure 5. The planned energy balance of the Finnish demo house. (Simulated by VTT)

3.1.2 Energy and building system description for the Finnish demo case

The positive energy building at Kalasatama is a co-operative effort of companies and research. The project demonstrates that the positive energy houses and nearly zero energy buildings are possible in cold climate with the existing technology. The hybrid geothermal energy system at Kalasatama building is a combination of semi-deep geothermal boreholes, heat pumps, solar photovoltaic panels and combined PV and thermal panels producing electricity and heat.

The hydraulic scheme of the energy system in presented in Figure 6.

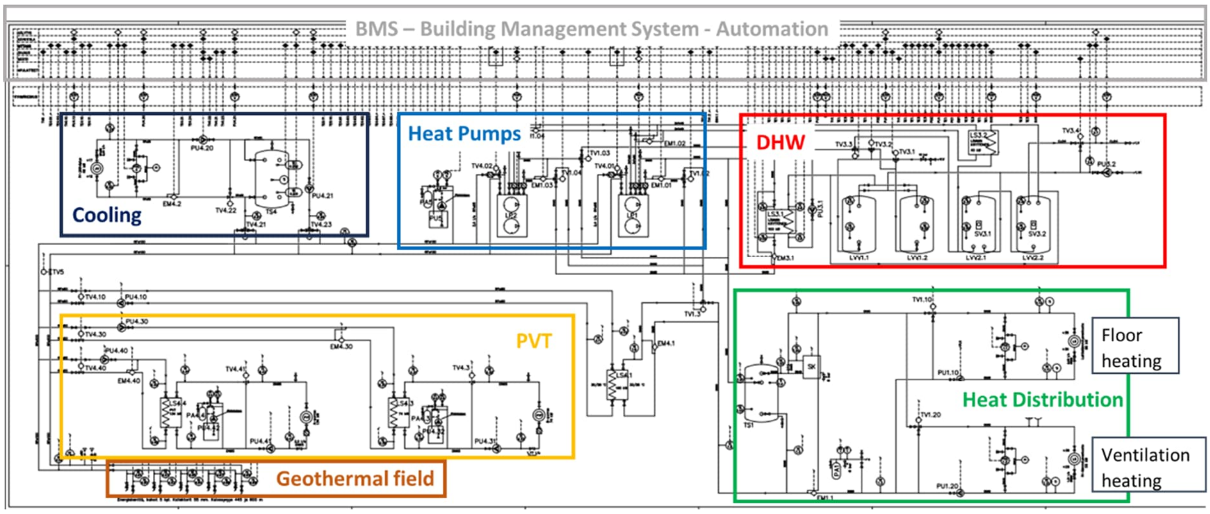

Figure 6. The hydraulic scheme of the energy system. (TAS, with edits by VTT)

Basso is developer of the project and coordinates the planning and construction. Tom Allen Senera is developing the concepts of semi-deep ground source, hybrid energy systems and smart building automation. Gebwell develops heat pumps integrated in the systems and Muovitech is focusing on improved collector design for semi-deep boreholes. VTT Technical Research Centre of Finland brings the knowledge in system design, smart control and optimisation, and simulation. VTT is also monitoring and evaluating the performance of the building and geothermal hybrid system after the apartments are occupied. Engineering company Sweco is responsible for the architectural and technical plans for Basso, which constructs the houses in 2021-23.

3.1.3 Selected KPIs for the Finnish demo case

The Finnish case has selected KPIs based on Table 11. The numbering shows 9 key indicators and non-numbered are giving additional information. Blue rows are giving recommendation of Genk KPI workshop. The heating degree days (HDD) and cooling degree days (CDD) give the indication of the temperatures of the year and will be used when normalize the heating and cooling performance for the reference year, in order to make different climatic years comparable.

The heating energy consumption indicates the heat demand in spaces, including space heating and heating for ventilation, with or without domestic hot water demand. The electricity energy consumption is given in a similar way, with or without electricity for HVAC and domestic hot water heating. The self-sufficiency rate is given at yearly period: the share of own PV and PVT electricity production compared to electricity need. Negative grid energy consumption means there is less local production than demand. The seasonal coefficient of performance SCOP will be calculated for heat production of the full energy system, with or without HVAC electricity.

Table 11. The main KPIs in Finnish demo case.

Domain			Unit		Unit
Energy	Energy consumption – heat - not including DHW & DHW circulation - including DHW &DHW circulation	64,3 183,8	MWh/a	15,4 44,0	kWh/m²a
	Energy consumption – electricity - not including HVAC, DHW, DHW circulation & cooling - including HVAC, DHW, DHW circulation & cooling	65,8 113,1	MWh/a	15,7 27,1	kWh/m²a
	Local renewable energy production	99,7	MWh/a	23,9	kWh/m²a
	Self-consumption rate		%		
	Self-sufficiency ratio (or load cover factor)	88	%		
	Domestic hot water consumption (incl circulation)	119,4	MWh/a	28,6	kWh/m²a
	Grid energy consumption (balance)	-13,4	MWh/a	-3,2	kWh/m²a
	Heating degree days HDD	3831	Kd/a	in 2021	
	Cooling degree days CDD	N.A.	Kd/a		
Economy	CAPEX – capital expenditures		€		
	OPEX – operational expenditures		€		
Technology	SCOP – seasonal coefficient of performance - for energy system, not including HVAC electricity - for energy system including HVAC electricity	4,2 2,2	number		
	PV efficiency - nominal/design values - seasonal	18,5 N.A.	%		
	Share of local electricity	88	%		
Social	Comfort		Likert		

3.1.4 Measurement plan for the Finnish demo case

The measurements are implemented in building automation system of Fidelix. The general system architecture is presented in *Figure 7*.

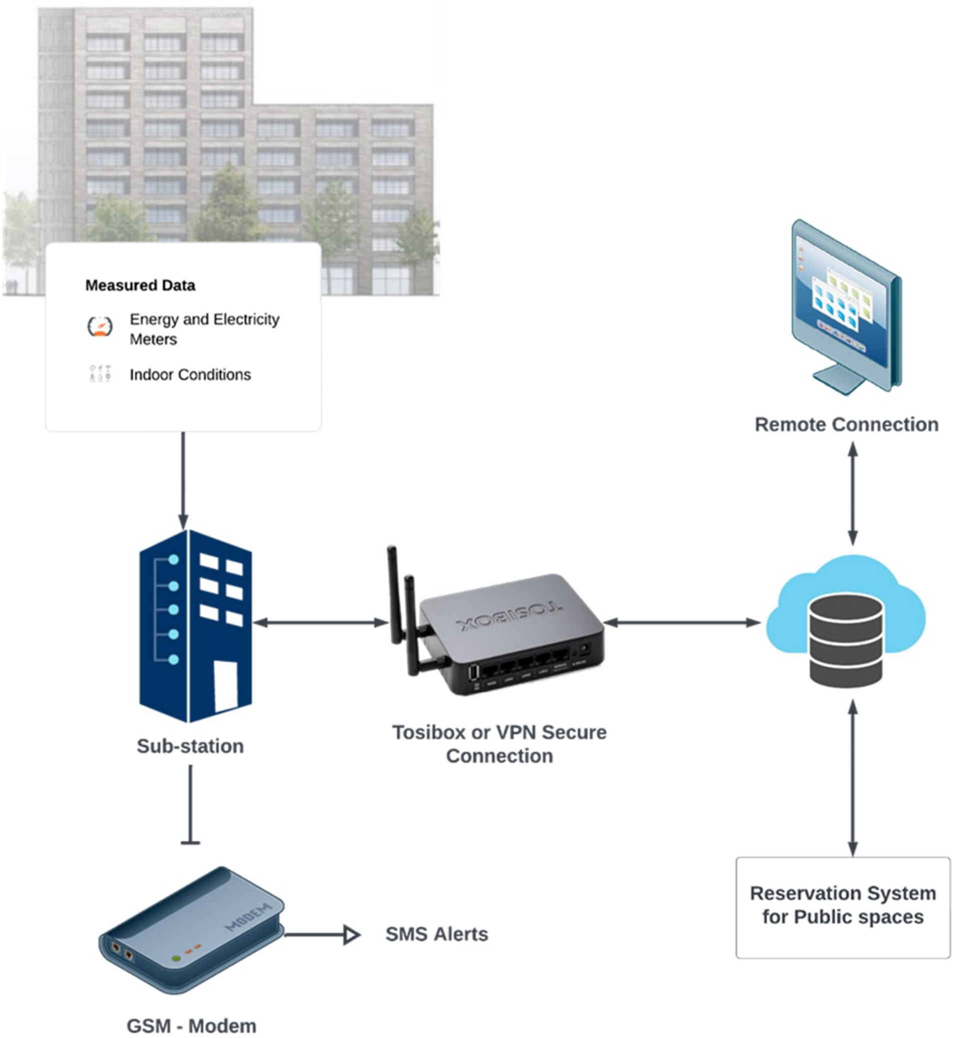

Figure 7. Architecture of building automation in demo case Finland.

The measured values of the system are given in details in device and sensor list (in Annex for D3.2, Latanis et al 2021). The system device and sensor lists in D3.2 are given for energy system (Figure 6), ventilation machines (Figure 26 in Annex 1) and room level devices (Figure 27 in Annex 1).

The measurements consist of

1. Temperatures TE-x.xx (supply and return of flows, air temperature)
2. Energy meters EMx.xx
3. Pressures PE-x
4. Pressure differences PDE-x or PE x
5. electricity of pumps PU x.xx
6. electricity of electric heating boiler SK
7. electricity of heat pumps LPx

8. Water flow meters VMx.x
9. Humidity ME x.xx
10. Occupancy sensor XS x.xx
11. Position of electromagnetic valve (ON/OFF) MV x.xx
12. Room air flow rate signal FC x.xx
13. Carbon dioxide CO_2 QE x
14. Fan speed indicator SCOx

The room level sensor Produal KLH 100 can be used for measurement and control of room temperature and relative humidity. Produal LA14E occupancy sensor is sensing the occupancy and/or sensing the movements.

Figure 8. Room controller Produal KLH 100 for temperature and relative humidity and occupancy or movement sensor produal LA 14E.

3.2 Demo case in Belgium

The demo site in Hasselt (BE) is part of a larger new-built residential area and it was completed in 2018. The project consists of 68 apartments and 22 houses intended for social housing. The EXCESS demonstrator is a part of this residential area including four apartment buildings with 20 dwellings (see Figure 9). The residential units are connected to a small district heating network which is heated by different thermal energy sources (geothermal heat pumps, gas-fired geothermal heat pumps and backup gas-fired boilers).

Figure 9. The Hasselt demonstration site.

In each residential unit, a substation is installed to use the local district heating network for space heating and domestic hot water production. In the EXCESS project the building will be converted to a positive energy building. This will be achieved by implementing innovations developed within the EXCESS project such as:

- PVT panels for renewable heat and electricity
- Multi-source and direct controlled heat pump
- MPC controller for optimization of the energy flows onsite
- Activation of thermal and electrical flexibility in the heat interface units within the apartments

3.2.1 Targets and goals of the Belgian demo case

Positive energy balance

The annual energy balance for the planned electricity consumption and production onsite is given in Figure 10. The total electricity consumption for the building (excl. plug loads in apartments) is estimated at approximately 49 MWh. The total annual electricity production form renewables onsite is expected to be +/- 52 MWh. The PVT installation with 85 panels (400W_p) will produce +/- 30 to 35 MWh, PV on the roof will account for 15 – 20 MWh. The output of the wind turbine is unclear at the moment due to technical problems with the generator.

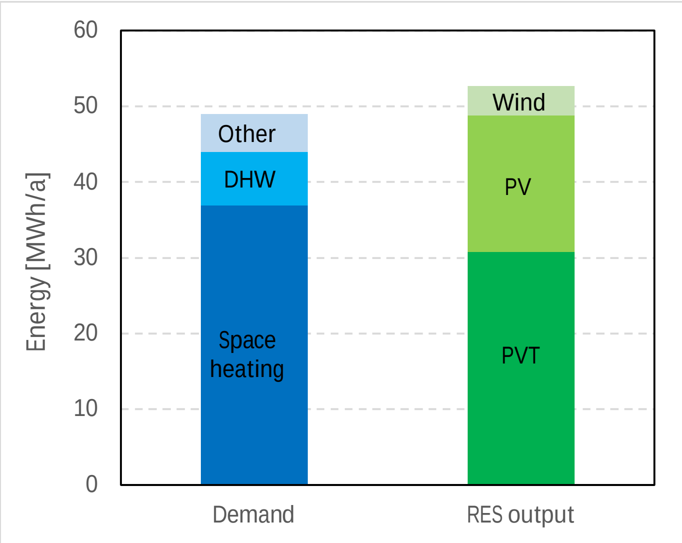

Figure 10: Annual energy balance in Belgian demo site

Activating energy flexibility in the system

The activation of energy flexibility in the system is another important target for the Belgian demo site. The MPC controller considers several sources of flexibility for the control decisions (Table 12).

Table 12. The sources of energy flexibility considered by the MPC controller in the Belgian demo site.

Flexibility source	Controllable asset/parameter
DHW storage in the heat interface units	DHW setpoint temperature
P2H elements in the thermal storages	Electrical and thermal load
Building thermal mass	Space heating setpoint temperature
Direct controllable heat pump	Compressor speed
Thermal network	Thermal load
Central thermal energy storage tank	State of charge

The DHW storage temperatures are closely monitored. In addition, some storage tanks are equipped with additional sensors to better understand the dynamics in the system and to calculate the current state of charge of the buffers. In Figure 11 a screenshot of the monitoring dashboard is presented with the DHW temperatures over a period of 6 hours. The MPC controller can set the current setpoint for DHW within in certain comfort band (e.g. 47 – 53°C).

The power to heat elements can provide additional heating capacity with a finer granular control. There are 20 P2H elements installed with a maximum output of 1.8kW.

The compressor speed of the heat pump can be set by the MPC controller. The heat pump is connected to a large thermal buffer to provide additional short-term storage to allow for a more dynamic heat pump operation. The heat pump is also connected to a larger heating network which makes it possible to provide excess heat to other buildings nearby.

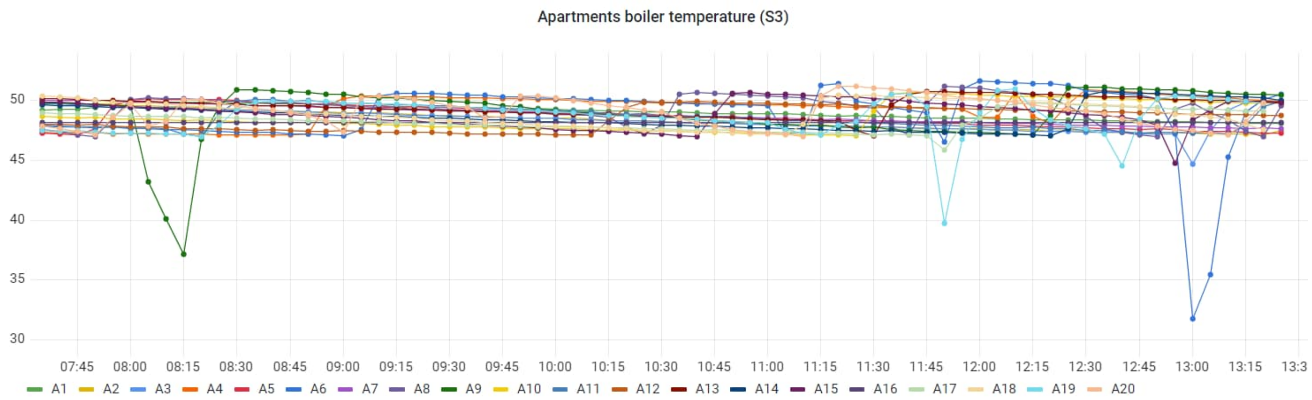

Figure 11: DHW storage tank temperatures in the apartments

3.2.2 Energy and building system description for the Belgian demo case

The four buildings are built on a large communal basement with car parking, storage space and room for the energy systems (Figure 12). The buildings have four floors, and the dwellings have different typologies:

- Single person apartment
- Family apartment

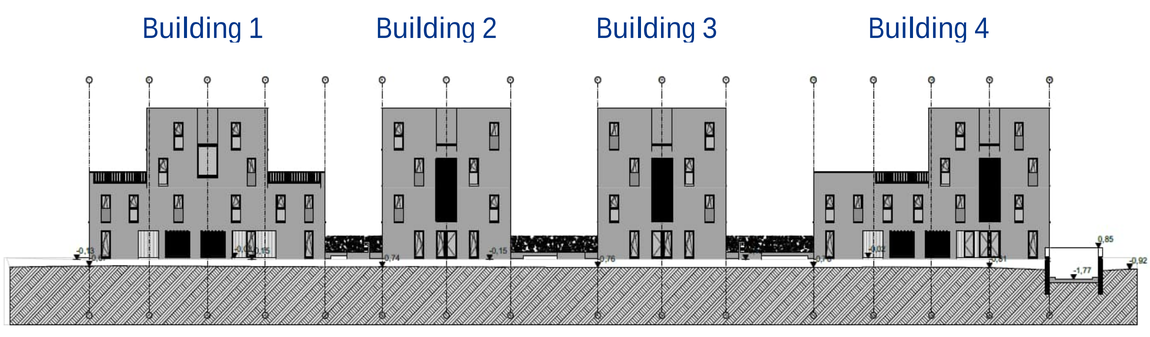

Figure 12: Overview of the 4 buildings in the Belgian demonstrator.

An overview of the apartments specifications is presented in Table 13.

Table 13: Building specifications related to insulation and energy performance levels

Building	Thermal zone	Floor surface [m²]	Average U-value of building envelope [W/m²K]	Loss surface area [m²]	Building volume [m³]
1	A101	116.89	0.35	261.55	2299.52
	A102	104.52	0.47	118.68	
	A103	104.52	0.47	118.68	
	A104	116.89	0.35	261.55	
	A121	118.87	0.37	219.65	
	A122	118.87	0.37	219.65	
2	A201	116.98	0.39	208.47	1413.44
	A202	116.9	0.39	208.47	
	A221	88.99	0.37	170.62	
	A222	88.99	0.37	170.62	
3	A301	116.98	0.39	208.47	1413.44
	A302	116.98	0.39	208.47	
	A321	88.99	0.37	170.62	
	A322	88.99	0.37	170.62	
4	A401	116.89	0.35	261.55	2248.82
	A402	105.57	0.39	179.01	
	A403	104.52	0.49	118.68	
	A404	116.15	0.39	208.91	
	A421	118.87	0.38	219.65	
	A422	102.49	0.39	166.56	

A small wind turbine is installed on the roof of building 3. The roof specification for building 1 and 2 is not ideal for the installation of PV and PVT given the relatively small surface area, building overhang and possible shade from the wind turbine(s). Therefore, the roof of another building next to the demo buildings was selected to install the PVT panels.

The buildings are currently heated by different heating systems (Figure 13):

- Gas-fired geothermal heat pump (35 kW_{th})
- Geothermal heat pump (20 kW_{th})
- Gas-fired boiler (140 kW_{th})

The gas-fired systems will be decommissioned and a new inverter heat pump with a maximum thermal output of 50 kW will be installed. Heat is injected in a small buffer tank which also acts as a balancing tank for the different heat generators. From the tank heat is distributed to the apartments via a district heating network. This network is also connected with other buildings nearby.

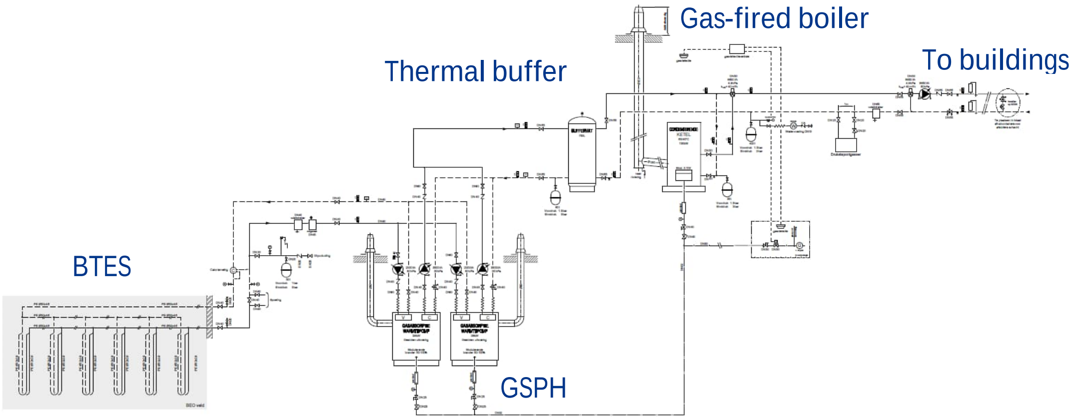

Figure 13: P&ID of existing heating system

A heat interface unit (Figure 14) is installed in each apartment. This unit includes a 90-litre boiler for domestic hot water storage. These storage tanks are equipped with electric heaters which can be used for boosting the domestic hot water temperature (e.g. Legionella prevention) and/or for low temperature district heating networks where the supply temperature is insufficient to generate domestic hot water inside the apartment.

Figure 14: Heat interface unit in one of the apartments

In the scope of EXCESS important improvements and modifications will be made to the energy system:

- Installation of 85 PVT panels
- Installation of a direct controllable multi-source heat pump
- Installation of low (12-25°C) – and high temperature (50-60°C) thermal energy storages
- Decommissioning of gas-fired heating systems
- Smart control layer over current rule-based control strategy
- Flexible heat interface units in the apartments

3.2.3 Selected KPIs for the Belgian demo case

A selection of KPIs was made for the Belgian demo case (Table 14).

Table 14. Key performance indicators for the Belgian demo site.

Domain	KPI	Value	Unit
Energy	Energy consumption - heat	77	kWh/m2·a
	Energy consumption - electricity	22	kWh/m2·a
	Local renewable energy production	30	kWh/m2·a
	Self-consumption rate		%
	Self-sufficiency ratio (or load cover factor)		%
	Electrical peak load		W/m2
	Energy flexibility		
	Grid energy consumption (balance)		kWh/m2·a
	Primary energy		kWh/m2·a
	Energy shared with adjacent buildings		kWh/a
Environment	CO_2 - reduction		Ton/a
Economy	CAPEX – capital expenditures		€
	OPEX – operational expenditures		€
	Pay back period		years
Technology	SCOP – seasonal coefficient of performance	3.5	number
	Forecasting accuracy (for MPC, control)		
Social	People reached		number
	User acceptance		Likert
	Comfort		Likert

3.2.4 Measurement plan for the Belgian demo case

An overview of the ICT network for measurements and data monitoring can be found in Figure 15. Measurement data is collected from the Building Management System (BMS) which operates on a local server in Cordium's network. VITO extracts the necessary data (only relevant data in the context of EXCESS) from this server by means of a PLC and gateway. Next, the data is sent to VITO's cloud platform where the data is stored. From this cloud platform measurement data can be shared with other parties (e.g. EXCESS data management platform hosted by Suite5) over a secured API.

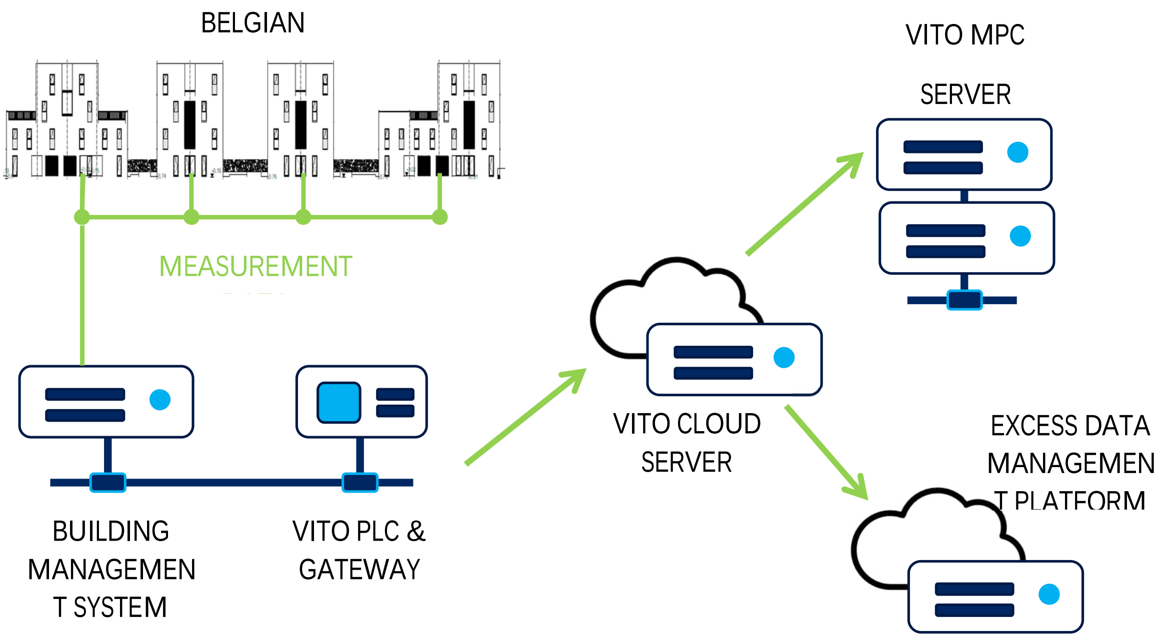

Figure 15: Measurement data ICT architecture with measurement data flow in the Belgian demo site.

An extensive list with measurement data is available in EXCESS Deliverable 3.2 (Latanis et al. 2021). In general, the following datatypes are captured, processed and stored in the EXCESS framework:

- Temperature (heating and cooling flow & return temperature, room temperature, ...)
- Flow (flowrates in the heat distribution circuits, PVT circuits and BTES circuit)
- Energy and power (Thermal and electrical consumption and loads)
- Voltage (PVT output and grid connection)
- Current (PVT output and grid connection)
- System states (device or component states)

The key aspects related to the dataset are presented in Annex 2.

3.3 Demo case in Spain

The Spanish demo case is located in the historical centre of Valladolid, a city characterized by a mild climate, with cold winters and hot summers. It is a protected classical Renaissance palace (XVI century, Figure 16). The project consists of an entire renovation of the internal distribution of the building to create nine dwellings, five of them in a duplex typology. Due to the heritage protection of the building, to minimize the energy demand, the envelope of the building has to be upgraded without modifying the exterior appearance of the façade, including the size and number and position of the windows. In addition, high performance HVAC systems will be installed, as well as the renewable energy systems that the architectural protection allows, in order to maximize the self-consumption of on-site generated RES.

Tuscan courtyard

Figure 16. Spanish demo case at Valladolid.

3.3.1 Targets and goals of the Spanish demo case

This demonstration building aims to serve as a blueprint for deep renovation of historic buildings towards PEB standards, becoming the very first positive energy historic building in Spain.

The solution designed for this building to meet the PEB standard relies on the design and deployment of a prototype of innovative smart energy system (Table 15). This prototype integrates different components and technologies: a centralized aerothermal heat pump with three types of on-site renewable energy production (BIPV skylight, PV panels and PVT panels), together with a storage system (ion-lithium batteries). The produced PV energy will supply energy to the building on a collective self-consumption mode, and the surplus will be stored in the batteries for daily use. When the batteries are fully loaded, the PV will feed the grid. PVT will also be installed to supply domestic hot water. The electro-mobility component will be integrated by deploying 2 EV charging stations completing the EXCESS PEB concept.

The PVT and PV panels will be provided by DUALSUN out of their remaining material budget, enabling DUALSUN to test their devices in an additional demo. This prototype of renewable energy system will be managed by means of an advanced BMS with demand response based in load management and weather forecast. Additionally, the high-performance building envelope with innovative materials and solutions will be deployed, to minimize the thermal energy demand of the building.

Table 15. Planned technologies to be integrated in the alternative demo pilot in Valladolid

Proposed Technologies	EXCESS PEB technology upgrade
• Aerothermal heat pump 40 kW • 55 kW PV • 2,8 Hybrid photovoltaic/thermal panels – PVT • Ion-Lithium batteries – 30 kWh • 2 eV charging stations	•Integrating PV, aerothermal heat pump with energy storage (battery) and electric vehicle charging system as one controllable system • Installation of lithium batteries for advanced energy flexibility service functionalities and electricity quality supply • Integrated controller (Task 2.5) for easing the integration and the management of the energy generated on site • HMI system (human-machine interface) for intelligent management of energy, management and control of the installation • Energy sharing and trading: BEMS will decide on the best strategy to reduce the overall energy consumption. Excess energy will be shared

The aim is to develop a concept that integrates already proven technological solutions in order to be able to replicate the concept and transform historical and protected buildings into PEBs. The simulated annual energy balance for the demo site is presented in Figure 17.

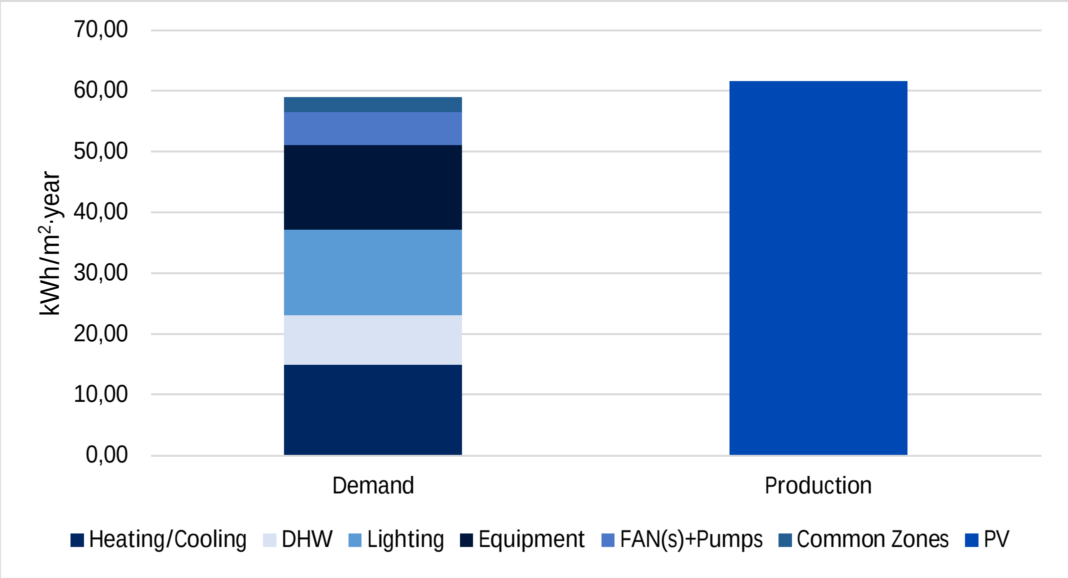

Figure 17. Annual energy balance for the Spanish Demo site (simulation). Source: CENER

3.3.2 Energy and building system description for the Spanish demo case

The energy system in the Spanish demo intends to minimise the energy consumption in the building, reducing the energy demand and increasing the overall energy efficiency while maximising the onsite renewable generation. The energy system scheme is shown in Figure 18.

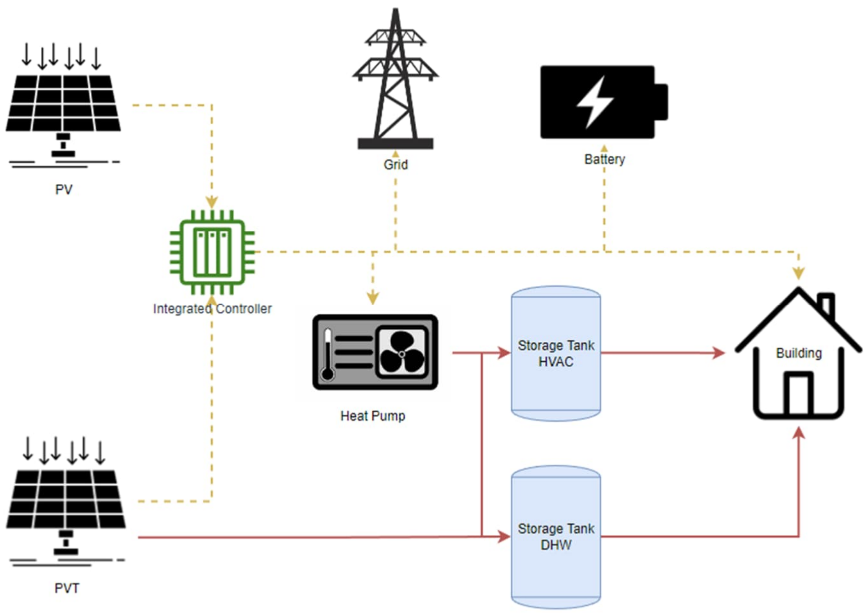

Figure 18. Energy system scheme. Source: CENER

The central thermal energy system is to be planned to include aerothermal heat pumps which provide the heating, cooling and domestic hot water (DHW) demand.

The thermal energy produced by the heat pumps is stored in two different thermal energy storages. One of them will supply thermal energy, both cooling and heating, and another will be dedicated to DHW production. The thermal energy distribution systems will transfer the heat stored in the tanks to the dwellings in order to fulfil adequate indoor comfort conditions. In this sense, the control strategy to be defined in the setup of the energy installation is of high importance to give flexibility to the market and adjust the energy operation to the required conditions.

The RES generation will be provided by PV and PVT panels installed on the roof of the building, where the heritage protection limitations allow. Even with the already mentioned restrictions and the fact of being in a dense urban environment with limited solar accessibility, the average solar radiation per square meter is high enough to cover the electric demand with onsite RES generation from PV panels.

Figure 19. HMI interface of the Integrated Controller. Source: CENER

The onsite RES generation will be managed by an Integrated Controller (IC), which enables advanced control functionalities based on weather forecasting and energy consumption estimations. The IC can be accessed by a Human Machine Interface (HMI, Figure 19) and decides on the energy flow from the electricity generated on the PV panels, whether to store it in 30 kWh batteries, to consume it in the building to sell it to the market. The energy system will also include the installation of 2 EV charging stations.

3.3.3 Selected KPIs for the Spanish demo case

The Spanish case has selected KPIs based on Table 16. The numbering shows 9 key indicators and non-numbered are giving additional information. Blue rows are giving recommendation of Genk KPI workshop. At the moment of writing this report only simulation values are available.

Table 16. Key performance indicators for the Spanish demo site.

Domain	KPI	Value	Unit
Energy	Energy consumption - heat	55.68	kWh/m2·a
	Energy consumption - electricity	59.46	kWh/m2·a
	Local renewable energy production	61.55	kWh/m2·a
	Self-consumption rate	45	%
	Self-sufficiency ratio (or load cover factor)	47	%
	Electrical peak load		W/m2
	Energy flexibility		
	Grid energy consumption (balance)	-2.09	kWh/m2·a
	Primary energy	-5.02	kWh/m2·a
	Heating degree days HDD	1781	d/a
	Cooling degree days CDD	394	d/a
Economy	CAPEX – capital expenditures		€
	OPEX – operational expenditures		€
	Pay back period		years
Technology	SCOP – seasonal coefficient of performance	2.87	number
	Forecasting accuracy (for MPC, control)		
Social	People reached		number
	User acceptance		Likert
	Comfort		Likert

3.3.4 Measurement plan for the Spanish demo case

The architecture of the monitoring system in the Spanish pilot is described in Figure 20.

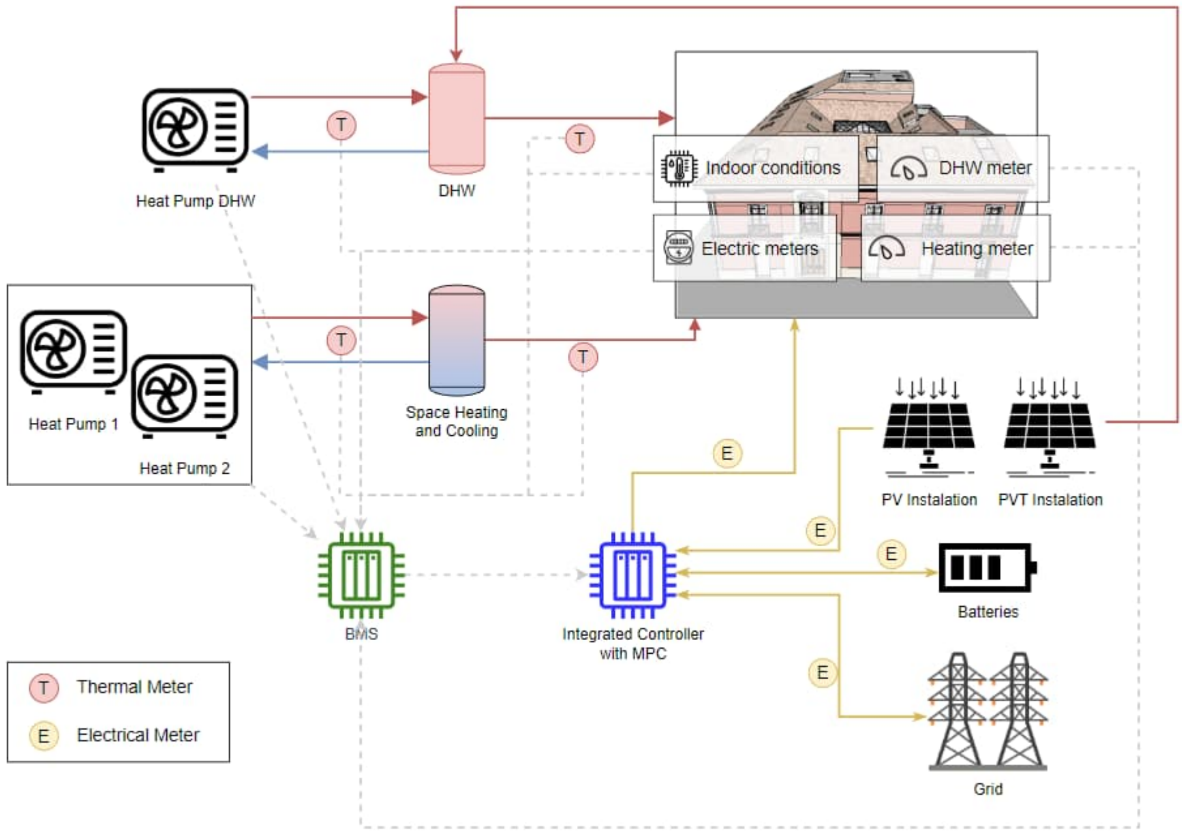

Figure 20. Scheme of the monitoring system in the Spanish pilot. Source: CENER

The sensor and meters at dwelling level are:

- Indoor conditions: indoor temperature (ºC), relative humidity (%), CO_2 concentration (ppm).
- Electrical consumptions from: fan units, lighting, electrical devices, total dwelling.
- Thermal consumption for: heating, cooling, DHW.

At building level:

- Outdoor conditions: outdoor temperature (ºC), global radiation on the horizontal (kJ/m^2), relative humidity (%).
- PV roof generation.
- Electric energy from/to battery.
- Electric energy from/to grid.
- Building consumption (electrical, thermal and water).
- Central thermal System Generation (electrical and thermal consumption).
- Thermal storage´s temperatures.
- Electrical consumption for pumps.

The sensors and meters communicate the data with the local BMS system that sends the data to the EXCESS Data Management Platform afterwards.

3.4 Demo case in Austria

3.4.1 Targets and goals of the Austrian demo case

A former commercial zone is transformed to an area with mixed use including offices, recreation zones as well as sports facilities and restaurants. In total, the 19 buildings in the area are being refurbished towards passive house standards while increasing the share of locally produced renewable energy (solar energy, small hydropower). Through the integration of innovative elements for load shifting, storage, user integration, interaction with the local electricity grid as well as a smart, predictive control, a maximum energy flexibility will be achieved, and the self-consumption will be increased.

Figure 21. Demo building in Austria (source BAR)

The EXCESS demo building (Figure 21) consists of ten floors, with a cafeteria in the basement and office space with temporary overnight accommodation. Several energy efficiency measures will be integrated, including a multifunctional façade (electricity generation, heating and cooling) that can be mounted to the exterior of an existing building to improve its energy performance. The central energy system in place for the area is a hybrid energy system. It combines a cascading heat pump system, PV panels on roofs and facades and a small hydro power plant that will produce electricity and heat for the building. Energy flexibility in the building is also maximized by thermal building mass activation, and decentralized buffer storages.

User centric applications will be a key innovation to facilitate the creation of an energy community. The application allows constant monitoring and verification of energy savings at the prosumer and the building levels and facilitates the transparent distribution of benefits arising from energy optimization among prosumers based on energy measurements handled through blockchain.

3.4.2 Energy and building system description for the Austrian demo case

Figure 22 shows the energy system concept to reach PEB for the demo building. It is split in 3 categories, System 1, which concerns only the demo building as energy system, System 2 where the hydro power plant produces additional electricity, and System 3 where the whole area interacts with the demo building. The goal is to already yield PEB with System 1 due to the innovative concept and not using the hydropower plant from System 2.

A heat pump system with a water-well as source is used to provide heating or cooling energy. The heat pump charges the domestic hot water (DHW) storage or the space heating (SH) storage that provides energy to the consumers. In summer cooling as free-cooling, directly from the water-well is foreseen and simultaneously cooling with DHW preparation is desired. A building integrated PV (BiPV) on south and west directions of the building is installed to reach PEB for System 1. Surplus of the gained electrical energy is sold to the power grid or stored to the battery (on community level but not considered in the energy balance of the demo building).

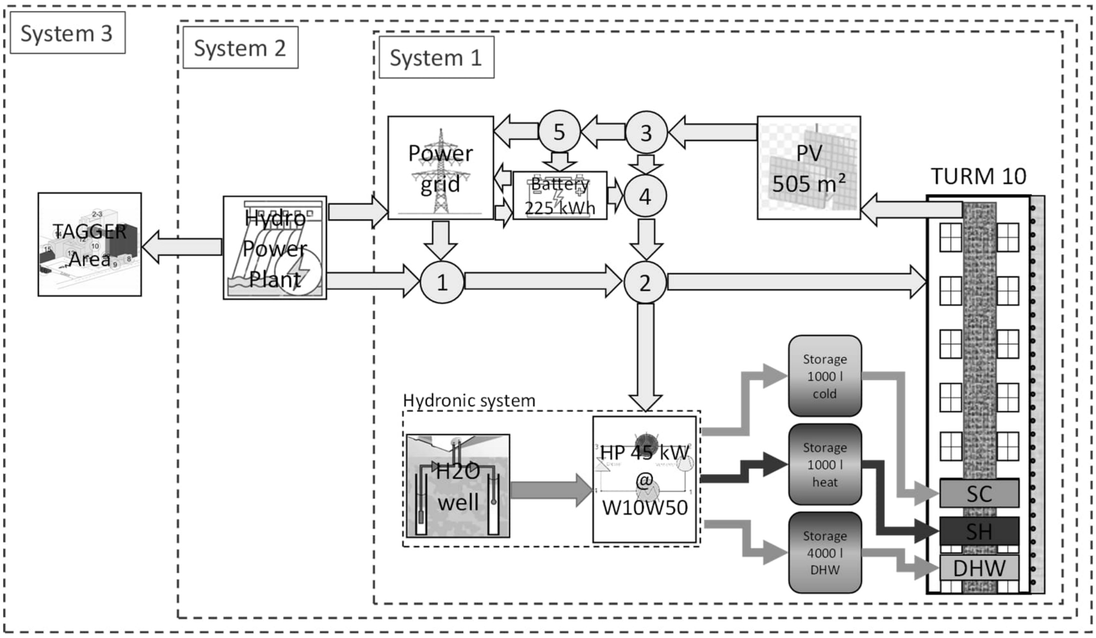

Figure 22: Whole building complex Tagger-Area and buildings with energy concept

Figure 23 shows the scheme of the hydronic system in detail with its design parameters. For the circulation pumps high efficiency pumps are assumed and the set points are 52 °C/48 °C for the storages DHW and SH, and 6 °C /12 °C for the cold storage. The heights of the sensors are 10 % for DHW and SH, and 95 % for space cooling (SC) based on max. high of the tank. The linkage part between building and plant is the multifunctional facade with the active layer to transfer heat to or from the existing wall that conditions the room behind.

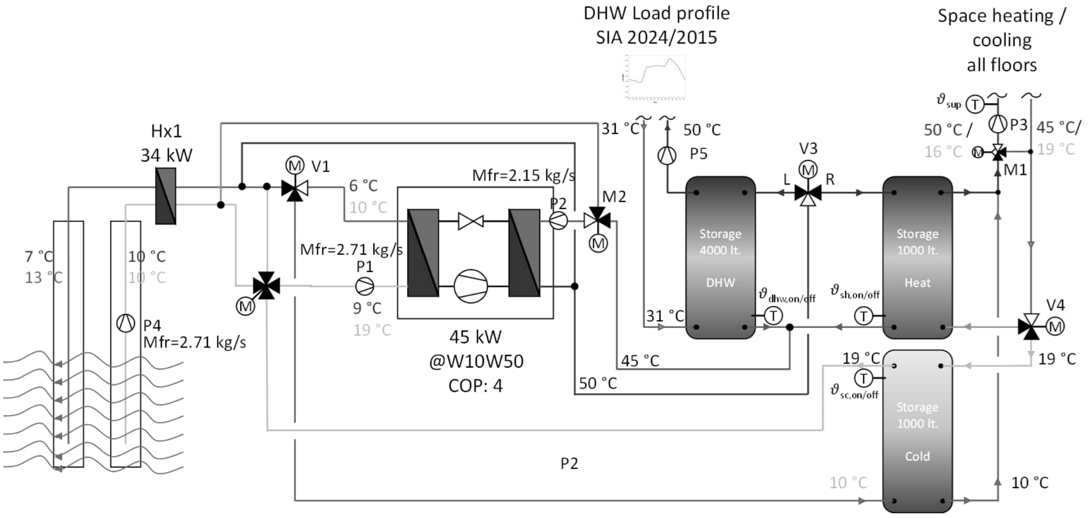

Figure 23: Overall scheme of the hydronic system with heat pump, water-well as source, storages (DHW and SH and cold) and distribution system

The arrangement of the heating elements is shown in Figure 24. In total, there are three supply lines that make it possible to operate almost all facade sides individually. Furthermore, each floor can be controlled individually.

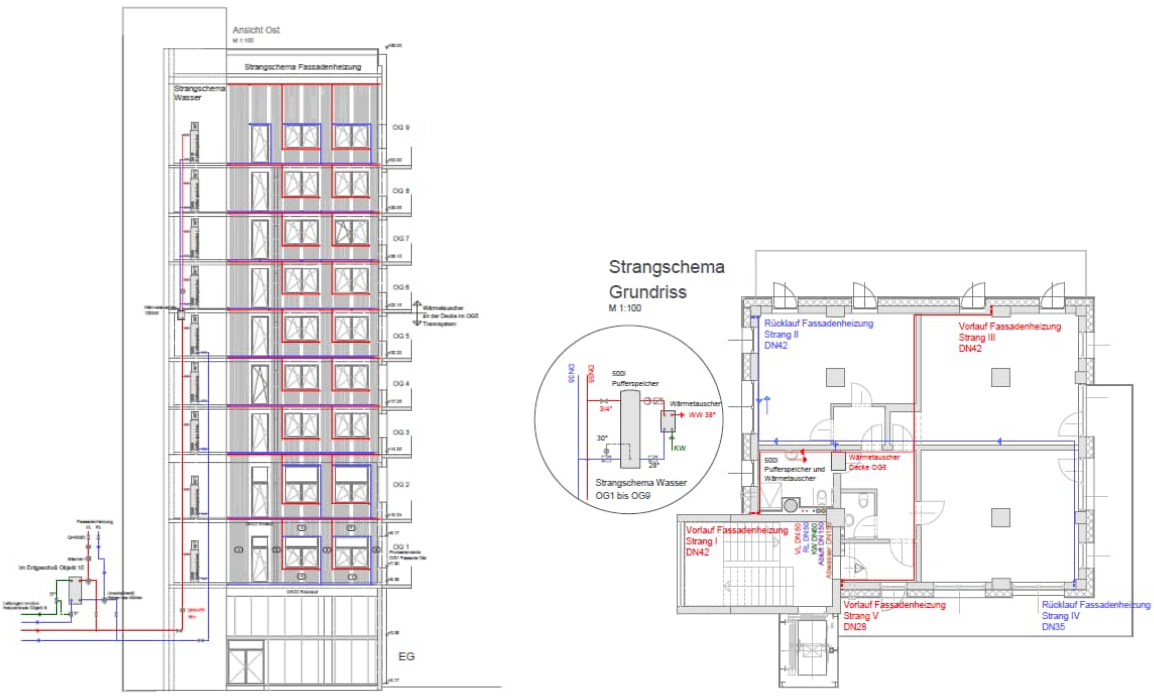

Figure 24: Hydraulic scheme of the energy active facade and the connection to decentralised water storage

3.4.3 Selected KPIs for the Austrian demo case

A selection of KPIs was made for the Austrian demo case. Table 17 presents the technical KPIs and their target values based on simulations.

Table 17: Technical KPI´s based on simulation

Technical KPI	Value	Unit
Annual thermal energy demand of the demonstrator building for space heating (SH)	30.4	MWh/a
Annual thermal energy demand of the demonstrator building for cooling (SC)	32.7	MWh/a
Annual thermal energy demand of the demonstrator building for domestic hot water (DHW)	15.8	MWh/a
Annual electrical energy demand (Lighting + Equipment) of the demonstrator building	21.9	MWh/a
Annual electrical energy consumption of the demonstrator building	42.0	MWh/a
Annual total electricity production by the PV	62.1	MWh/a
Energy balance (final energy) of the demonstrator building on annual basis	20.1	MWh/a
Supply cover factor (percentage of on-site generation that is used by the building)	35.7	%
Load cover factor (percentage of the electricity demand covered by on-site electricity generation	52.7	%

The planned energy balance based on electricity (final energy) of the Austrian demo house is presented in Figure 25.

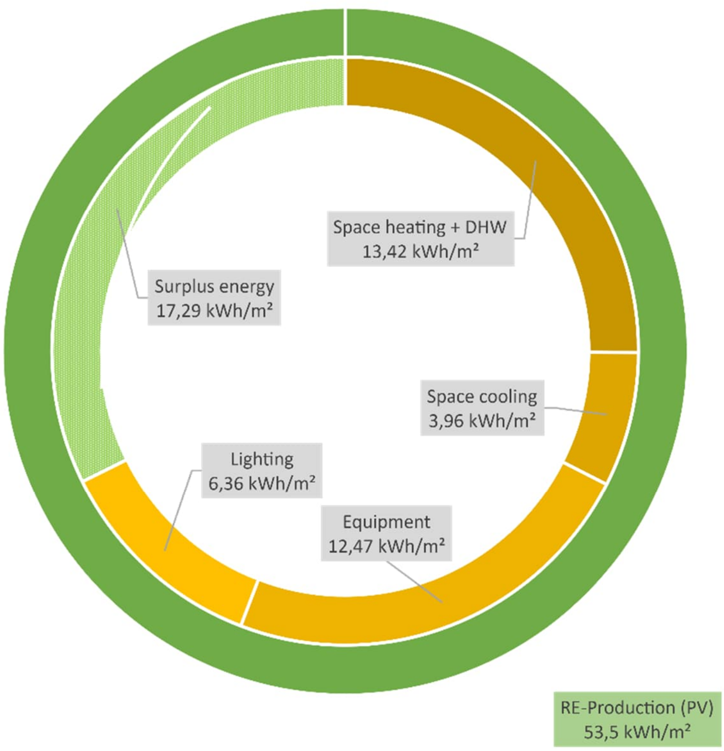

Figure 25: Planned energy balance of the Austrian demo

The energy flexibility KPIs for the Austrian demo are presented in Table 18, the economic KPIs in Table 19 and the social indicators in Table 20.

Table 18: Energy flexibility KPI´s for the Austrian demo

Energy flexibility KPI	Indicator
Structure storage capacity C_ADR	kWh
Building mass storage efficiency η_ADR	%
Non-thermal grid interactive period	h

Table 19: Economic KPI´s for the Austrian demo

Economic KPI	Indicator
CAPEX - CAPital EXpenditures	€
OPEX - OPerational EXpenditures	€
LCE - Levelised cost of energy	€/MWh

Table 20: Social KPI´s for the Austrian demo including those related to OBS App

Social aspect	KPI	Indicator
General	Thermal comfort	Based on indoor air quality
	User acceptance	Based on complaints / interviews
	User engagement / people reached	%
OBS App related KPIs	Ease of use of the digital app	Likert scale
	Number of users involved in developing the app	# of people
	Readability and usability of the app for vulnerable groups	Likert scale
	Change in the level of awareness of technology (renewable energy) for the users	Likert scale

3.4.4 Measurement plan for the Austrian demo case

In the Austrian demo measurements will be done at different levels.

At building level:

- Outdoor conditions:
    - outdoor temperature (°C),
    - global radiation on the horizontal (kW/m^2),
    - relative humidity (%).
- Heat and cold generation (heat pump):
    - Temperature (heating and cooling flow & return temperature) (°C)
    - Flow (flowrates in the heat distribution circuits) (L/min)
    - Energy and power (Thermal energy and electrical consumption) (Wh, W)
    - System states (device or component states)
- Electricity production of façade integrated PV (energy, power) (Wh, W)
- Electricity consumption from the grid (W)

At apartment level:

- Thermal consumption for heating, cooling, DHW (Wh)
- Indoor conditions: indoor temperature (°C), relative humidity (%), CO_2 concentration (ppm), room luminance, set point temperature (°C).
- Electrical consumptions from: lighting, electrical devices, total dwelling (Wh)
- Thermal storage temperatures (°C)
- Occupancy detection

4 EXCESS KPI recommendation

The EXCESS team has elaborated the KPIs in desk work and two workshops. The EXCESS KPIs are summarised in four domains: energy, economy, technology and social indicators (Table 21). The four demo cases have selected their indicators from these tables based on the main interests in the case.

The workshop at Genk summarised the main interests of four demo groups as brainstorm session (blue rows in table). In energy domain, the biggest interest was in renewable share, self-consumption rate of local renewables and self-sufficiency ratio describing the share of own local production compared to demand. The energy flexibility and CO_2 emissions were seen as a big value for energy positive buildings. In economic domain, the capital costs, operational costs and life-cycle costs were recognised as key performance indicators. In technology domain indicators, seasonal coefficient of performance is describing performance and efficiency of the technology and gives a good indicator for development of the technology. Robustness and stability were seen as basic requirements for the energy systems. In social indicators, the variety of KPIs is large leaving the selection for each case separately. The user satisfaction, comfort and visibility of the results were recognised as the main social indicators. The workshop results and associated tables were given as information and checklist for the demos, which made the own selections for their cases.

The common KPIs for all four cases (4/4) are:

- Grid energy consumption showing the balance of grid injection and off-take.
- Local renewable energy production
- Self-consumption rate
- CAPEX – capital expenditures
- OPEX – operational expenditures

KPIs for at least for 3 cases (3/4):

- Energy consumption - heat
- Energy consumption – electricity
- Self-sufficiency ratio (or load cover factor)
- SCOP – seasonal coefficient of performance
- Comfort

The rest of the KPIs were selected only for one or two cases. The selection of case specific KPIs showed the different approaches in different countries and projects. In general, it would be interesting to get all the KPIs from all the cases, but this is not possible due to amount of measured data and questionnaire studies needed for these. For this reason, the final selection of KPIs was given for each case. The list of selected indicators presented for each demo in Chapter 3 is preliminary and may change or additional indicators will be added when the operational phase starts.

In addition to those listed in Table 21, the availability of the critical raw materials has been recognised as a future challenge at EU-level, and it would be relevant to include a KPI for this, too. Those raw materials that are most important economically and have a high supply risk are called critical raw materials. Critical raw materials are essential to the functioning and integrity of a wide range of industrial ecosystems. E.g. gallium and indium are part of light-emitting diode (LED) technology. Semiconductors need silicon metal. Hydrogen fuel cells and electrolysers need platinum group metals. Access to resources is a strategic security question for Europe's ambition to deliver the Green Deal.

Table 21. Summary of key performance indicators for PEBs in general, in four demo cases (✓) and recommendations of EXCESS workshop (in blue).

Domain		Unit	FIN	BEL	SP	AUT
Energy	Energy consumption - heat	kWh/a	✓		✓	✓
	Energy consumption - electricity	kWh/a	✓		✓	✓
	Local renewable energy production	kWh/a	✓	✓	✓	✓
	Renewable share	%			✓	
	Self-consumption rate	%	✓	✓	✓	✓
	Self sufficiency ratio (or load cover factor)	%	✓		✓	✓
	Cooling energy consumption	kWh/a				✓
	Domestic hot water consumption	kWh/a	✓			✓
	Lighting energy consumption	kWh/a				
	Plug loads energy consumption	kWh/a				
	Electrical peak load	kW			✓	
	Energy flexibility			✓	✓	
	Energy shared with adjacent buildings			✓		
	Grid energy consumption (balance)	kWh/a	✓	✓	✓	✓
	Primary energy	kWh/a			✓	
	CO2 emissions	ton CO_2		✓		
	Heating degree days HDD	Kd/a			✓	
	Cooling degree days CDD	Kd/a			✓	
Economy	CAPEX – capital expenditures	€	✓	✓	✓	✓
	OPEX – operational expenditures	€	✓	✓	✓	✓
	Life cycle cost	€/N year				
	Levelized cost of energy	€/MWh				✓
	Revenue	€		✓		
	IRR – internal rate of return	%				
	Net present value	€		✓		
	Pay back period	years			✓	
	Economic balance (costs vs revenue)	€				
Technology	SCOP – seasonal coefficient of performance	number	✓	✓	✓	
	State-of-charge of storages	%		✓		
	PV efficiency	%				
	Forecasting accuracy (for MPC, control)			✓	✓	
	Level of integration	Likert				
	Interaction level					
	Robustness					
	Stability					
	Share of local electricity	%				
	Share of open technology	%				
	Conformance with standards	Likert				
	ICT solutions implementation	%				
	Data security	Likert				
	Data privacy	Likert				
Social	People reached	number		✓		
	People reached in target group	%				
	Increased consciousness of citizens	Likert				
	Increased participation of vulnerable groups	Likert				
	Professional stakeholder involvement	Likert				
	Use of the inputs from stakeholders	Likert				
	Job creation	number				
	Local community (citizens, residents) involvement in planning	Likert				
	Ease of use for end users	Likert				
	Ease of use for professional stakeholders	Likert				
	Advantages for end users	Likert		✓		
	User acceptance	Likert		✓	✓	
	Visibility of results	Likert				
	User satisfaction	Likert				
	Comfort	Likert	✓	✓	✓	✓
	Privacy	Likert				
	Health	Likert				
	Gender equity	Likert				
	Safety	Likert				

5 Conclusions

The report explains in detail the possible key performance indicators for EXCESS PEB buildings, and the choices made for each of the four cases. In energy domain, the biggest interest in EXCESS was in renewable share, self-consumption rate of local renewables and self-sufficiency ratio describing the share of own local production compared to demand. The energy flexibility and CO_2 emissions were seen as a big value for energy positive buildings. In economic domain, the capital costs, operational costs and life-cycle costs were recognised as key performance indicators. In technology domain indicators, seasonal coefficient of performance is describing performance and efficiency of the technology and gives a good indicator for development of the technology. Robustness and stability were seen as basic requirements for the energy systems. In social indicators, the variety of KPIs is large leaving the selection for each case separately. The user satisfaction, comfort and visibility of the results were recognised as the main indicators. The workshop results and associated tables were given as information and checklist for the demos, which made the own selections for their cases.

The common KPIs for all four cases (4/4) or three of the four cases (3/4) are:

- Grid energy consumption showing the balance of grid injection and off-take (4/4)
- Local renewable energy production (4/4)
- Self-consumption rate (4/4)
- CAPEX – capital expenditures (4/4)
- OPEX – operational expenditures (4/4)
- Energy consumption – heat (3/4)
- Energy consumption – electricity (3/4)
- Self-sufficiency ratio (or load cover factor) (3/4)
- SCOP – seasonal coefficient of performance (3/4)
- Comfort (3/4)

The selection of case specific KPIs showed the different approaches in different countries and projects. In general, it would be interesting to get all the KPIs from all the cases, but this is not possible due to amount of measured data and questionnaire studies needed for these. For this reason, the final selection of KPIs was given for each case.

The next step in the demos is to implement the monitoring plan and start measuring the data (or collect the information by other methods, e.g. user questionnaires), which is needed for key performance indicators. In the evaluation phase the measured KPIs will be compared to target values, showing the performance of the PEB case.

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Annex 1. Detailed measurement architecture for the Finnish demo

The measured values of the system in the Finnish demo are given in details in device and sensor list in EXCESS D3.2 (Latanis et al 2020) and component connection chart schematic drawing is presented in Figure 7. The system device and sensor lists are given for energy system (Figure 6), ventilation machines (Figure 26) and room level devices (Figure 27).

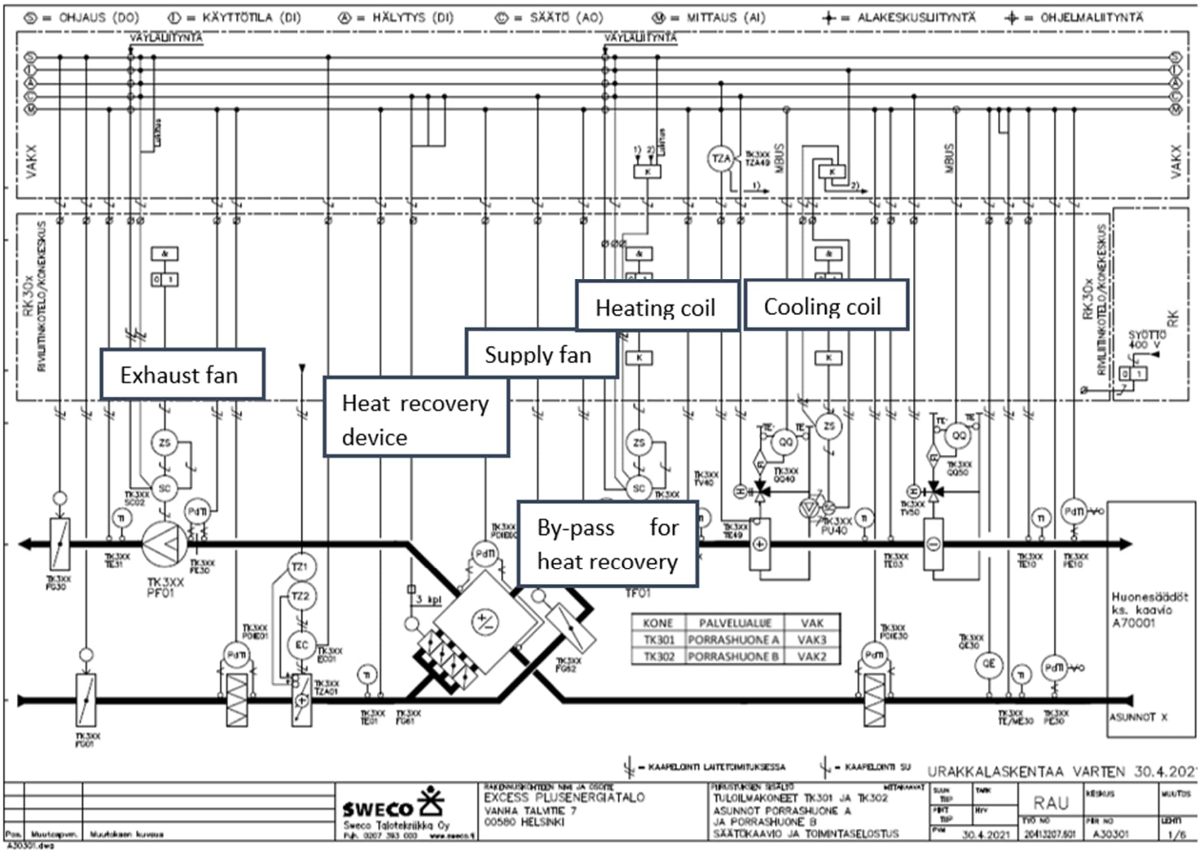

Figure 26. Ventilation machine connection chart.

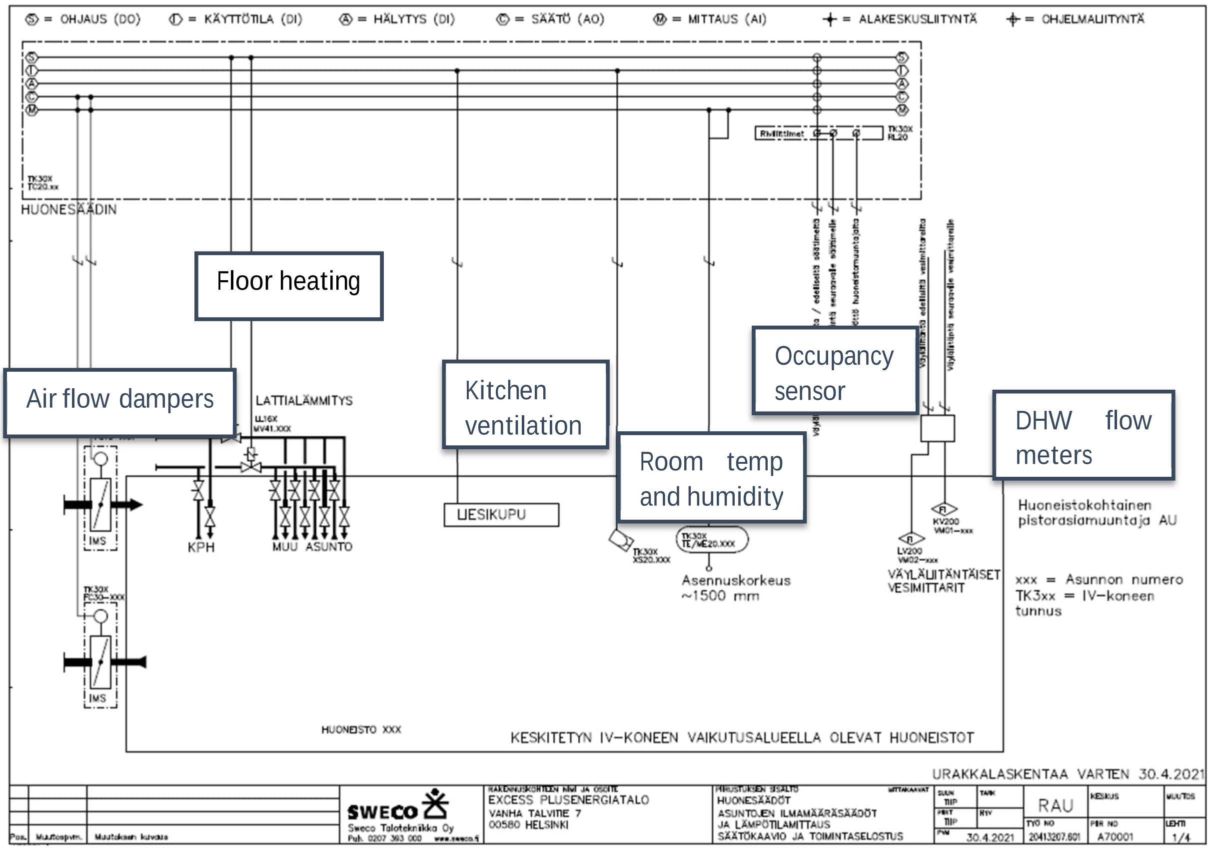

Figure 27. Room device connection chart.

Annex 2. Data inventory for the Belgian demo

Key aspects related to the data collection in Belgian case are presented in Table 22.

Table 22. The key aspects related to the dataset

Dataset name	Cordium demosite
Data owner	Cordium
Type of data	Temperatures, flows, energy consumptions etc.
Size of the dataset	+/- 1.600 points sampled each 5-15min.
Data access VITO	Direct from BMS (source) and over secured API
Data access Excess partners	Over secured API
Data access other parties	Data not available for third parties
Metadata	Embedded in the data structure
Data preservation beyond end of project	To be discussed with Cordium