D9.1

TEST CASES, ASSESSMENT FRAMEWORK and KPIs

SUMMARY

This document develops a detailed description of the test cases in the GENTE pilot projects and presents the assessment framework and key performance indicators for the validation of the GENTE tools.

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Impressum

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Abstract

The ERANET GENTE project aims to develop a distributed governance toolbox for local energy communities (LECs). This toolbox includes advanced digital technologies such as the internet of things (IoT), distributed ledger technology (DLT), edge processing and artificial intelligence (AI) for autonomous energy resource management within and across LECs and for flexibility provision to energy networks.

The solutions developed within GENTE for the governance of LECs will be validated first at the lab levels, and then in real full-scale environments in order to increase the technology readiness level (TRL) levels of solutions. For that, GENTE project elements will be tested in several pilots with diverse characteristics. This variety of pilots, from labs to real environments, provides a good representation of LECs. In total, GENTE has 6 demonstrators at different scales in Sweden, Switzerland, and Turkey which can demonstrate solutions for new types of technologies and services in different technical, environmental and market contexts.

The main use cases to be validated are grid flexibility provision through the self consumption optimisation or peak load management, community CO_2 emissions reduction, energy efficiency improvement based on the energy cost reduction and autarky increase, community federation, and the co-design process for energy communities.

Within this document, for each site, the functional performance tests to verify the communication and operation of GENTE components are described. Tests for the evaluation of the accuracy of forecasting algorithms are also included. Then, all the test cases are described in detail, including the Key Performance Indicators that will be calculated in each, the baseline that will be used to estimate the savings in the cases is required, and the prerequisites for each test. In addition to the test cases at each pilot, some test cases for energy federation assessment are included.

Finally, a detailed list of all the Key Performance Indicators that are used for project validation and assessment are defined, and the calculation methodology that will be applied is explained.

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List of Abbreviations

AI	Artificial Intelligence
CELL	Collaborative Energy Living Lab
CO_2	Carbon dioxide
DLT	Distributed ledger technology
DSO	Distribution System Operator
EEM	Energy efficiency measure
ER	Exploitable Results
EV	Electric Vehicle
ICT	Information and communications technology
IoT	Internet of Things
IPMVP	International Performance Measurement and Verification Protocol
KPI	Key Performance Indicators
LEC	Local Energy Community
LL	Living Lab
NTO	Non-technical objective
PV	Photovoltaics
RES	Renewable Energy Sources
TO	Technical Objective
TRL	Technology Readiness Level
UC	Use case

Introduction

The ERANET GENTE project aims to develop a distributed governance toolbox for local energy communities (LECs). This toolbox includes advanced digital technologies such as the internet of things (IoT), distributed ledger technology (DLT), edge processing and artificial intelligence (AI) for autonomous energy resource management within and across LECs and for flexibility provisions to energy networks.

The solutions developed within GENTE for the governance of LECs will be validated first at the lab levels, and then at real full-scale environments in order to increase technology readiness level (TRL) levels of solutions. GENTE project will be tested in several pilots with diverse characteristics. This variety of pilots, from living labs to real environments, provides a good representation of LECs. In total, GENTE has 6 demonstrators at different scales in Sweden, Switzerland, and Turkey which can demonstrate solutions for new types of technologies and services in different technical, environmental and market contexts.

This document presents the GENTE validation methodology. The different steps performed for the definition of the GENTE validation are presented:

- Definition of the GENTE use cases (UCs).
- Mapping of the project exploitable results (ERs) to be tested, the characteristics and needs of the pilots and the GENTE UCs.
- Definition of the validation layers for GENTE solutions.
- Definition Key Performance Indicators (KPI) for the assessment framework.
- Indication of the performance measurement standard followed for the validation.

Then, a detailed description of the test cases in each pilot and all the KPIs used for the assessment are presented.

As a result, a guideline with the validation process to be followed in the demonstration tasks of GENTE is achieved.

GENTE validation overview

This section describes the methodology followed to define the validation process for the GENTE solutions. The validation process aims to determine the degree of accuracy of a development from the perspective of the intended uses. A development may have different objectives for which it must be validated. Thus, a development commonly has to satisfy different requirements, and sometimes, it is necessary to carry out the validation process using different tests.

In order to define the whole validation process, the following steps have been conducted:

1. **Definition of the GENTE use cases** to understand which objectives are targeted to be accomplished and validated in GENTE.
2. **Mapping between the use cases, project's exploitable results and pilots** characteristics and needs, to have a clear roadmap of what will be integrated, tested and validated in each demonstrator.
3. Definition of a **validation methodology** and the **test cases** to get a guideline of the tests that will be required for the validation in each pilot.
4. Definition of the **Key Performance Indicators** for assessment in all the domains that are considered in GENTE project.

Each of these steps is detailed below.

GENTE use cases definition

A **use case** can be defined as an specific objective that the system has to accomplish. Thus, it is important to highlight GENTE project's objectives.

In order to achieve the goal of a toolbox for communities for resource optimisation and community federation, and to promote the creation of new communities, GENTE has the following specific technical objectives (TOs) and non-technical objectives (NTOs):

- **TO1** - Develop and demonstrate scalable technology for autonomous orchestration of electricity, heat and eMobility assets within and across communities (based on IoT, edge) bringing intelligence to distributed physical assets, considering data security,interoperability, and privacy.
- **TO2** - Develop and integrate modules for forecasting using edge-based processing, including developing/providing optimisation algorithms for distributed control as well as reduced models to inform model predictive control.
- **TO3** - Build the intelligent assets and forecasting into a DLT-based framework for identification and traceability of community energy resources, as well as digital identity management of the community members and the other stakeholders.
- **TO4** - Develop and demonstrate a community platform for decision making and resource control that will support secure and resilient energy systems.

- **NTO1** - Accelerate the economic viability of Local Energy Communities (LECs) through Community Federations and business models based on energy resource optimisation.
- **NTO2** - Accelerate the creation of LECs by providing the framework in Living Labs across Europe. Maximise energy efficiency and balance and increase the interactions with the energy market;
- **NTO3** - Promote engagement in LECs, and support the non-economic benefits of community energy, including self-governance, through innovative products and services.
- **NTO4** - Define and incorporate need owner requirements in platform design and replication toolkit.

Considering these objectives, the following use cases (UC) have been identified for GENTE, presented in Table 1.

Table 1 - GENTE use cases definition.

# Use case	Use case definition
UC1	Grid flexibility provision
UC1a	Self consumption optimisation
UC1b	Peak load management
UC2	Community CO_2 emissions reduction
UC3	Energy efficiency
UC3a	Reduction in community energy costs
UC3b	Increase in community autarky
UC4	Community federation
UC5	Co-design process for LEC

Mapping use cases, exploitable results and pilots

The next step in the validation process is mapping these three pillars: the GENTE use cases, the exploitable results that are the outcome of the project, and the different pilots of GENTE. This process is represented in Figure 1.

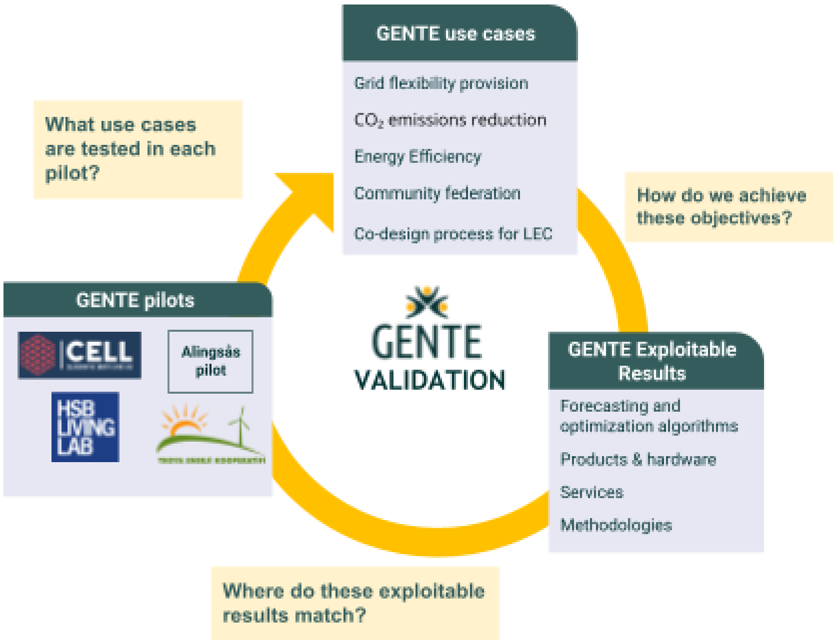


Figure 1 - Process scheme for the definition of the GENTE test cases.

The multi-domain use cases stated in GENTE are demonstrated and validated by defining and measuring the exploitable results from the GENTE project. Once these outputs of the project are clearly identified, a mapping between the exploitable results and the different GENTE pilot sites is conducted by answering the following questions:

- *Where can these exploitable results be tested? Which pilots comply with the testing requirements?*
- *Where is it interesting to test them because of the users' needs and interests?*

Thus, considering the characteristics and available energy assets in each pilot, and the needs of each pilot, it is decided where each exploitable result is most relevant.

The different exploitable results developed in the GENTE project have been identified in Task 4.3 (*Market, stakeholder, and competence analysis to support and manage the exploitable results*). These exploitable results are classified according to the categories of algorithms, products, methodologies, and services. A selection has been made of the exploitable results that are likely to be tested and integrated into a pilot, leaving out those that represent more general project outcomes. The selected exploitable results are represented in Table 2.

Table 2 - GENTE exploitable results list.

#ER	Name	Short description	Partners involved	Type
1	Heat forecast	Forecasting algorithms of thermal (heat) demand based on data analytics	Chalmers	Algorithms
2	PV forecast	Forecasting algorithms of PV production based on data analytics	HSLU, Chalmers, Smart Helio	Algorithms
3	Load forecast	Forecasting algorithms of consumer load curves based on data analytics	HSLU	Algorithms
4	Building optimisation	Optimisation algorithms for energy management at building level. Optimisation targets: CO_2 emissions reduction, cost minimisation, comfort assurance.	Chalmers, R2M	Algorithms
5	LEC optimisation	Optimisation algorithms for the energy management at LEC level. Optimisation targets: CO_2 emissions reduction, cost minimisation, comfort assurance.	HSLU, Chalmers	Algorithms
6	PV optimisation	The algorithm enables PV system managers' to dynamically optimise the production from the PV system.	Smart Helio	Algorithms
7	Grid services optimisation	Flexibility provision to the grid by the management of the resources and demand in the LEC.	Chalmers, HSLU	Algorithms
8	Community federation	Algorithms to perform an optimisation across communities (federation of communities).	HSLU, Chalmers	ALgorithms
9	LEC digital twin	A digital twin of an LEC to be used as a testbed for validation.	R2M	Algorithms
10	User-engagement activities	User-engagement based on the definition of a co-design process involving LEC users and stakeholders.	HSLU	Methodologies
11	IoT BEMS including heat pump	BEMS to interface with the users of the building (washing machines controller and EV charger), forecast the demand and make decisions to	Chalmers	Product

		minimise the energy cost and peak, control the operation of energy resources in real-time.		
12	Sub-metering device for PV systems	Consists of (1) a production device capable of measuring current, voltage and temperature of selected PV modules and uploading data values to the cloud for analysis, and (2) a prototype device that computes forecasts on-device based on locally stored values. Devices can work together or as standalone solutions.	Smart Helio	Product
13	DSO contracting platform	Simulation of contracting and settlement certification between DSO and service providers.	Prosume	Product
14	IoT platform	Advanced cloud-based energy IoT platform with platform-as-a-service data analytics solution for integration of distributed assets, data sources and stakeholders. The platform enables real-time monitoring and control of LECs.	Reengen	Product
15	Mobile app	One-Stop-Shop as a mobile-first app with powerful metrics, personal energy management and best practices awarding system.	Prosume	Product
16	DLT-based prosumer account platform	Definition, development and implementation of a decentralised identity management service for prosumers.	Prosume	Product
17	DLT-based community manager platform	Definition, development and implementation of a platform that enables incentives sharing Community and Federation approaches.	Prosume	Product
18	Communication between gateway and devices	Interface for managing data transfer between gateways and devices. Each local gateway will host an optimisation algorithm that will analyse local device data and determine setpoints. Local gateways will also interact with a central hub that is hosted either on an additional Reengen gateway or on a local server.	Reengen	Product
19	Edge computation in IoT gateway	The functionality to perform computation of forecasting and optimisation at IoT gateway level.	Reengen, HSLU	Product and algorithm

20	Hybrid control system for optimal dispatch between heat pump and district heating	A heat pump control and management platform (hybrid control system) that allows a DSO with district heating to optimise choice of heating source based on real-time market data.	Energy Save	Product

The exploitable results were mapped with the different pilot sites considering both the technical and social characteristics of each site. This mapping activity was conducted with all the GENTE partners, so that both representatives of the pilot sites (who know the sites' needs and characteristics) and developers of GENTE solutions (who know the requirements that are asked for the testing of each solution) took part in the process.

As a result, Figures 2-4 were obtained, which include an overview of what will be tested in each pilot site.

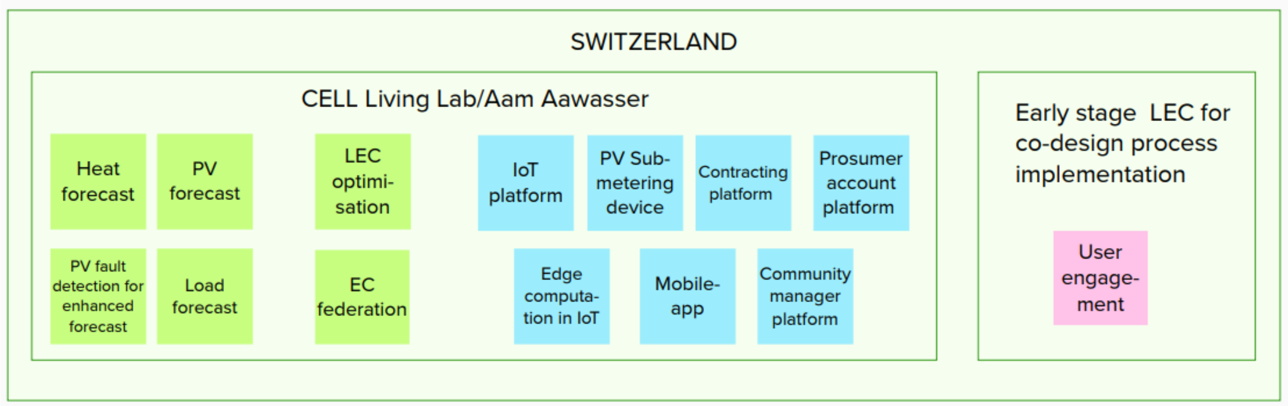


Figure 2 - GENTE exploitable results to be tested in Swiss demo-sites.

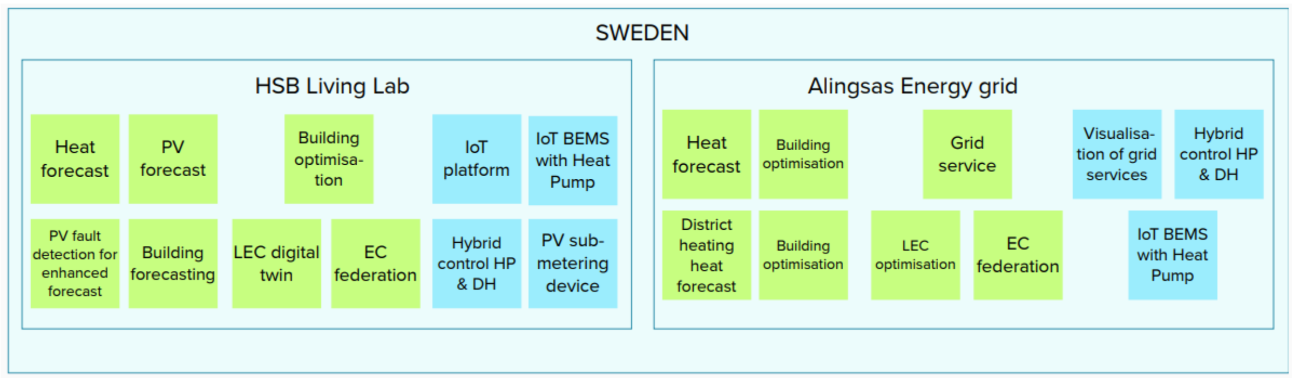


Figure 3 - GENTE exploitable results to be tested in Swedish demo-sites.

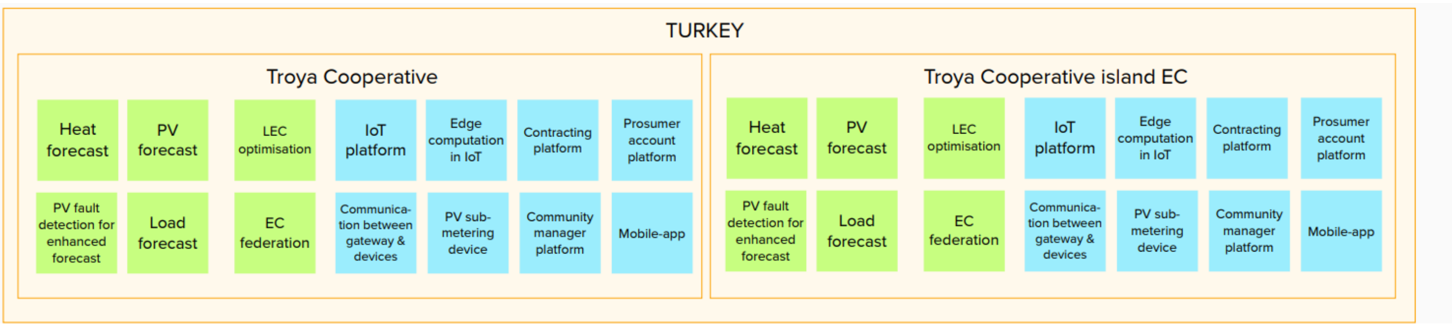


Figure 4 - GENTE exploitable results to be tested in Turkish demo-sites.

This mapping is fundamental to understand which new hardware needs to be integrated in each pilot, to have a clear overview of the technical architecture in each demonstration site, and to define the tests for each site.

As a next step, the GENTE use cases are matched to the different pilots considering this previous mapping with the exploitable results, and having in mind the different needs and interests of each LEC.

As a result, Figure 5 represents the use cases of each pilot.

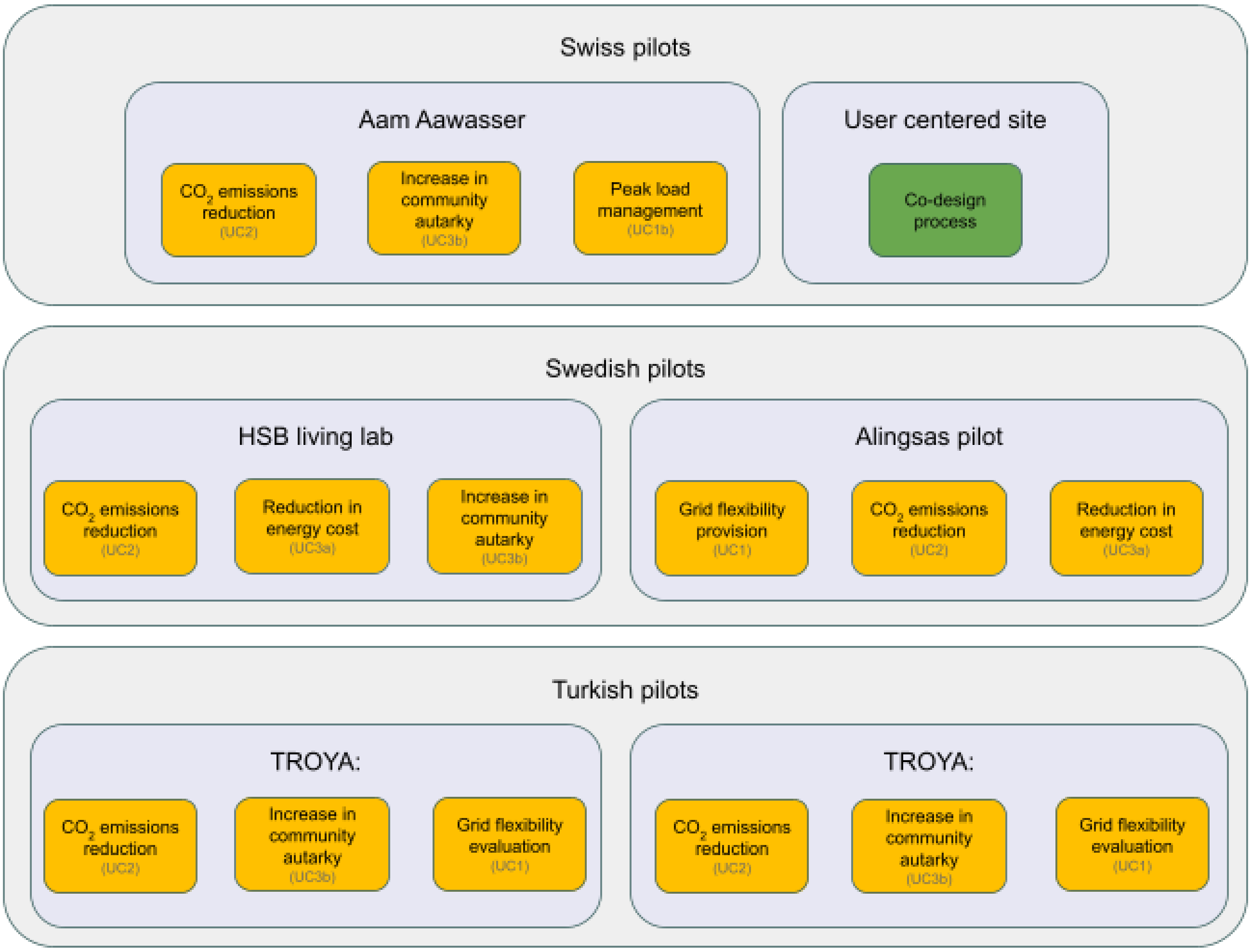


Figure 5 - GENTE use cases at each demo-site.

GENTE Validation methodology and test cases

A validation methodology has been defined in the GENTE project. The aim of this methodology is to guarantee that the GENTE solutions achieve the targeted objectives in the pilots. For the technical developments, that is, the GENTE toolbox solutions, the process consists of a three level validation for the technical developments that includes the verification of the integration of the solution, the evaluation of the forecasting services, and the validation of the specific GENTE objectives. This methodology is enriched with an evaluation of the impact of the user-engagement activities developed within GENTE. Moreover, the user-engagement is also assessed to evaluate the co-design process. This methodology is presented in Figure 6.

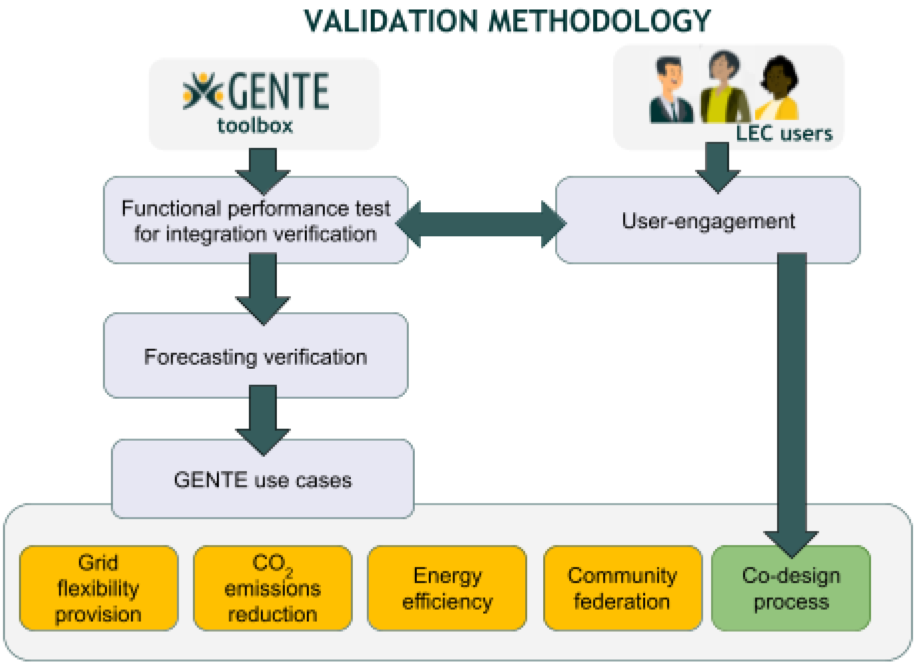


Figure 6 - GENTE validation methodology overview.

The first layer of the technical validation, **Functional performance tests for the integration verification**, is envisioned to check the correct installation and operation of the hardware developed or enhanced during the project.

The next layer ofthe technical validation, **Forecasting verification**, consists of an evaluation and assessment of the accuracy and validity of the prediction algorithms developed within GENTE that will provide required inputs to the optimisation algorithms. Having a good estimation of the errors of these forecasting algorithms is important for the uncertainty evaluation.

The last layer, **GENTE uses cases validation**, is the testing level focused on validating the specific targets of GENTE.

For the user-engagement centred activities, a parallel evaluation methodology has been defined.

Once this validation methodology is defined, the test cases for each demonstrator are defined. In GENTE, we use the term **test case** to refer to the testing and verification of a use case in a specific pilot.

Each test case is defined to validate the mission of a development in the context in which it will be operational. The definition of test cases is a key part to properly validate the functionalities or services provided by a development.

Key Performance Indicators for assessment

The assessment in GENTE will be performed by measuring and calculating the required Key Performance Indicators (KPIs). A **KPI** is a value that can be measured and is used for the evaluation and demonstration to assess the performance to achieve a specific target.

A set of KPIs are defined at each validation level so that the required demonstration aim is achieved at each layer. These KPIs relate to the different validation levels as shown in Figure 7.

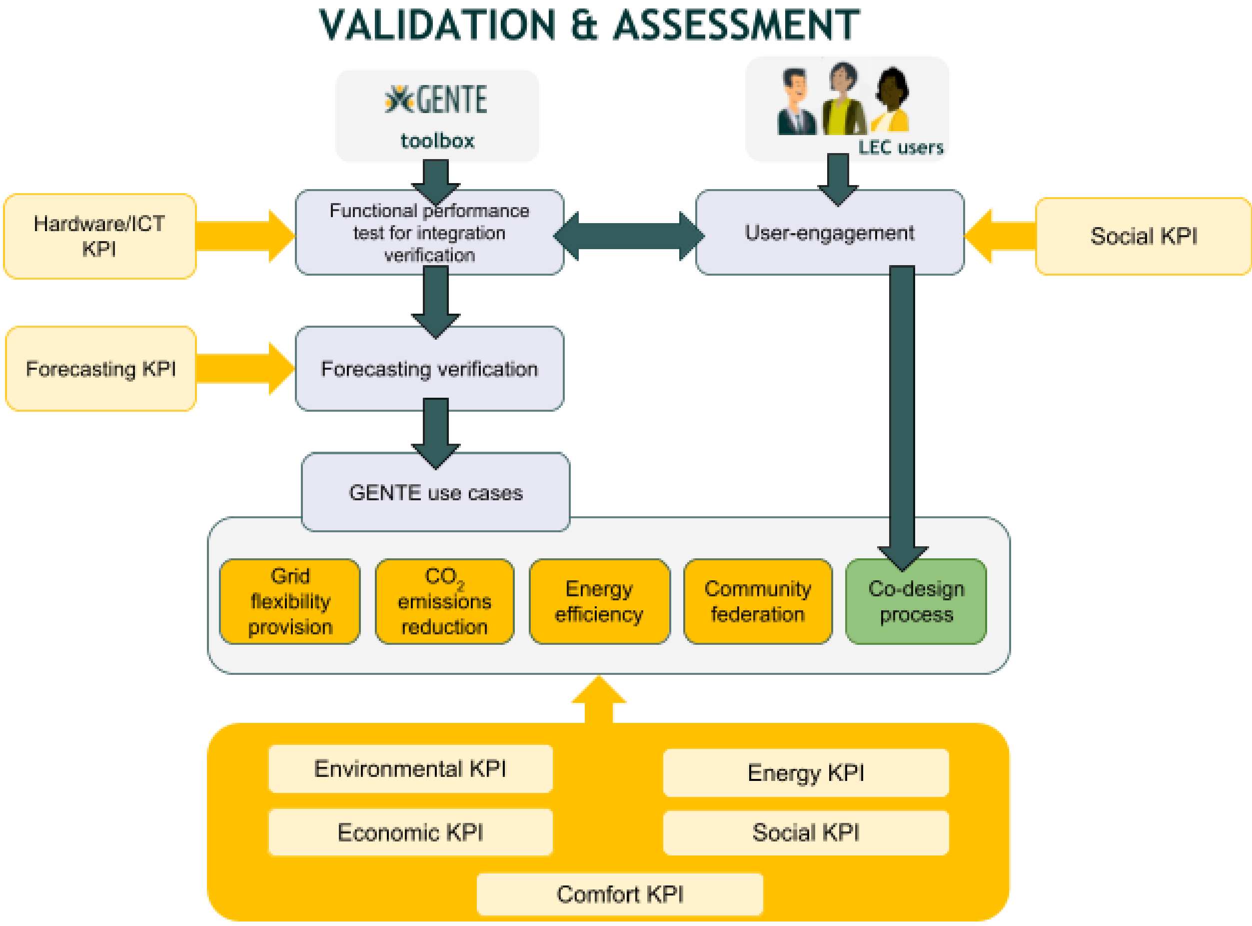


Figure 7 - GENTE validation and assessment framework overview.

KPIs in the following domains are included for GENTE:

- **Hardware/ICT KPIs**: for the assessment of the functional performance of the new hardware and ICT resulting from GENTE.
- **Forecasting KPIs**: for the assessment of the forecasting algorithms performance and accuracy.
- **Energy related KPIs**: for the assessment of targets related to the energy domain.
- **Environmental KPIs**: for the evaluation of the environmental impact.
- **Social KPIs**: for the objectives in the social domain.
- **Economical KPIs**: for assessment related to economic aspects.
- **Comfort KPIs**: for the evaluation of thermal comfort conditions.

Performance measurement standards

Evaluating the savings of an energy related project is a crucial point, no matter if they are energy, CO_2 emissions, cost or demand savings. The savings can not be directly measured because they represent the absence of a consumption or demand. The *International Performance Measurements and Verification*

Protocol (IPMVP)[1] presents a standard and consistent methodology for the evaluation of the savings. It compares the measured energy consumption or demand before and after the application of an energy efficiency measure (EEM), performing the corresponding adjustments for changes in conditions.

According to their definition, IPMVP "*defines standard terms and suggests best practice for quantifying the results of energy efficiency investments and increasing investment in energy and water efficiency, demand management and renewable energy projects*".

The IPMVP is based on the following formula for the calculation of *savings* or *avoided consumption or demand*.

$$Savings = (Baseline\ period\ energy - Reporting\ period\ energy) \pm Adjustment$$

The baseline period is the period before the implementation of the EEM and the reporting period refers to the period after this implementation and it is used to evaluate the performance of the EEM. The "Adjustments" term is used to restate the energy use or demand of the baseline and reporting periods under a common set of conditions. These adjustments are made using either mathematical models or physics-based models of energy consumption and/or demand. The conditions often considered for this adjustment are weather conditions, degree days or other independent external variables.

This procedure is represented in a time-series form in Figure 8.

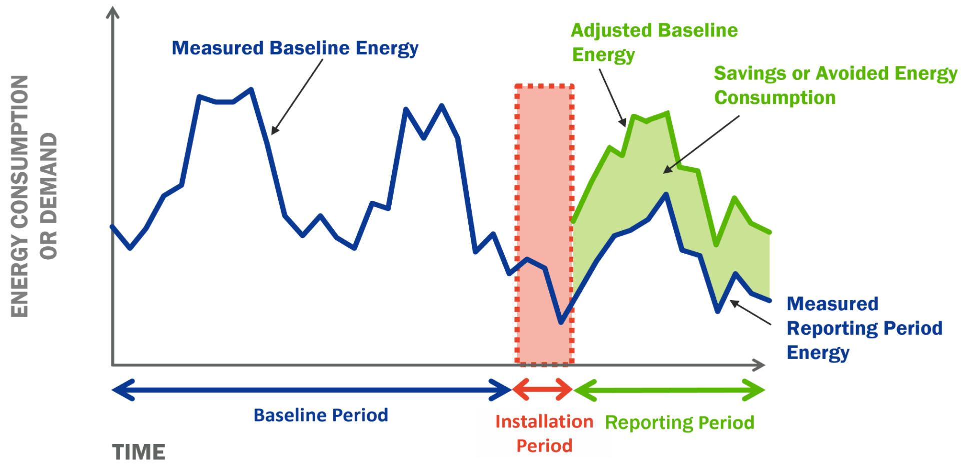


Figure 8 - Savings calculation based on the IPMVP[1].

The IPMVP standards will be used as a reference to generate the baseline models that will be used in the validation process. The steps described in the protocol will be followed to build the baseline models:

- In each test site, the boundary of the system will be defined, specially to determine the energy assets that are considered as well as the buildings of the LEC.
- The baseline model will be generated using the available historical data. For that, the independent variables that influence the studied consumption will be identified (weather variables, time variables such as the day of the week or the month). The proposed model in the

[1] [IPMVP - Efficiency Valuation Organization (EVO) (evo-world.org)](evo-world.org)

IPMVP (mainly, polynomial regression models) will be used to calibrate a baseline model with the available historical data and the independent variables.

- The reference values indicated in the IPMVP protocol for the errors that are recommended for the calibrated baseline model will be used just to assess the uncertainty in the calculations.
- The KPIs that refer to savings (energy, cost, ...) will be calculated as the difference between the baseline model (computed with the testing boundary conditions) and the measured values with the GENTE developments.

Test cases definition

In this chapter, the test cases for each country and each LEC are presented with a description of the objectives, procedure and requirements for each test case.

Swiss test cases

Switzerland includes two demo-sites. The first, Am Aawasser, is an LEC acting as a “self-consumption community” that provides a test facility equipped with local PV generation, run-of-river hydropower, electric vehicle (EV) charging, building automation, and community energy optimisation. Am Aawasser will be used as a test site focused on the integration of energy management solutions. The second pilot site, still to be confirmed, will be a housing complex that is considering establishing an energy community. This second site will be used to implement and evaluate co-design practices in a new energy community setting.

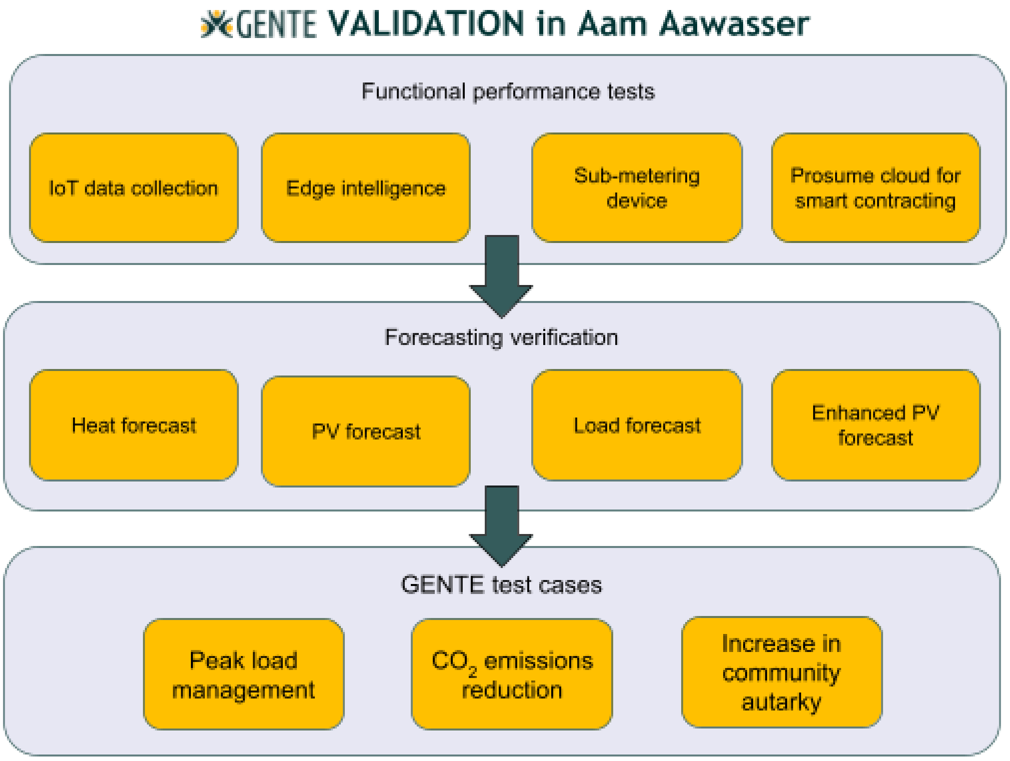
Am Aawasser LEC’s overview

The Am Aawasser community has 26 apartments and a commercial space of 600 m^2 (Figure 9, 10). The community is able to achieve a high level of autarky: there is local electricity production onsite (run-of-river hydro, rooftop PV) and controllable energy resources (heat pump, local energy storage, controllable building services and comfort settings). The hydro energy source has 85 kWp and produces around 51 MWh/y, the PV has 109 kWp and produces around 75 MWh/y. The battery and thermal storage capacity are 260 kWh, and 10.5 m^3, respectively. The electric usage for the community as a whole is around 140 MWh/y.

The Am Awasser community has an existing optimisation platform provided by third party company Eco Coach. The platform provides basic user controls, and is connected to the EcoCoach cloud based on MS Azure. The EcoCoach Cloud uses an API for accessing the data generated by various sensors located onsite.

Figures 9 & 10 - Am Aawasser LEC pictures.

Figure 11 provides an overview of the information about the GENTE validation process for the Am Aawasser site. The process includes the elements that require functional performance tests so that the integration part is verified. The forecasting algorithms that will be tested in Am Aawasser are also included. The last part of the validation process refers to the GENTE test cases in Am Aawasser.



Figures 11 - Am Aawasser validation process and test cases.

Functional performance tests in Am Aawasser LEC

Table 3 contains a detailed description of the four functional performance tests to be conducted in Am Aawasser.

Table 3 - Functional Performance tests in Am Aawasser.

FUNCTIONAL PERFORMANCE TEST #1 Am AAWASSER	
Test name	**Functional performance test for IoT data collection**
Developments to test	Data should be collected and stored locally on an IoT gateway or local community server, then made available for community optimisation using an IoT platform. In Am Aawasser, due to the presence of an existing platform, data consolidation will be tested both on an HSLU server and, if possible, on the Reengen gateway.
Objective	Demonstrate that data can be collected, consolidated and made available to the upstream processes on both an optimisation server and the IoT gateway.
Scope	Assets to monitored:

	• PV system • Heat system • EV charging station • Battery storage • Smart meter
Description	Data collection and consolidation will take place on a local Reengen IoT gateway using the API service provided by EcoCoach. Data will be transferred and stored securely using appropriate Reengen privacy preserving protocols / security protocols. Data will be made available to a ring-fenced computational instance on an HSLU server.
Prerequisites	The IoT gateway needs to be installed and available.
Assumptions	The presence of existing cloud infrastructure means that data connections are likely to be cloud-cloud.
Measured and calculated variables	• Electricity production, by source (PV/hydro) • Electrical storage (dis)charging power, state-of-charge, availability (for EVs) • Electricity consumption, • Electricity import/export • Heat production, by producer type (heat pump / immersion heater) • Heat storage temperatures and flow • Heat consumption by end-usage
Benchmark	Data will be available at the resolution required for forecasting and community optimisation, as defined in the respective functional performance tests.
FUNCTIONAL PERFORMANCE TEST #2 AM AAWASSER	
Test name	**Functional performance test for edge intelligence**
Developments to test	The GENTE optimizer provides the intelligence to meet the objectives of the use cases described elsewhere in this document . This tool, developed by HSLU in WP5, makes decisions on flexible assets while taking into account electricity prices, weather forecasts, energy consumption forecasts, and community optimisation targets, as defined in use cases. The tool is deployed on-site, either on existing computational resources, or on the Reengen IoT gateway. The optimiser uses site and cloud data to complete its functions, which can be summarised as: • Receiving requests and boundary conditions for optimisation • Conducting energy resource forecasts • Calculating and determining setpoints

	• Pushing setpoints to energy resources • Verifying device shift to setpoint The functional performance test for edge computation will assess the operation of the optimisation algorithm. Forecast performance tests for forecasts are described in the next section.
Objective	Verify the correct, accurate execution of the edge computation processes.
Scope	The whole LEC is considered. Assets to be monitored and/or managed will differ from test site to test site. At Am Aawasser, these include: • PV system • Hydro power • Heat pump • EV station • Battery storage • Smart metres • Level of grid import / export to community The optimisation algorithm will define set points for the heat pump and battery storage. EV charge optimisation (V1G) may be possible, but it cannot yet be confirmed at the time of writing this deliverable. Building energy management systems and building comfort settings, as well as settings for individual energy resources other than those listed above (e.g. appliances), will not be possible at Am Aawasser. It is assumed that forecasting can be achieved on the Reengen IoT gateway and the SmartHelio edge device. Forecasting research should include investigation of suitable forecasting frameworks to ensure models can be deployed onto the gateway. The location of the optimisation algorithm is assumed to be either: 1. On the Reengen IoT gateway, or 2. On an HSLU cloud resource. In both instances, access to site data will be achieved by connecting to the Eco Coach cloud via API. The use of a ‘demilitarised zone’ on the Eco Coach server is also being investigated.
Description	Functional performance tests include verification of: • Data pull to IoT gateway / cloud instance • Calculate and determine setpoints

	• Setpoint push • Verify device shift to setpoint Functional tests will first run in simulation in the HSLU laboratory, and then directly at Am Aawasser using a locally installed Reengen gateway.
KPIs	Hardware / ICT KPIs: • **KPI_IoT_3:** Algorithm and forecast execution performance
Prerequisites	Ongoing cooperation from existing optimisation platform provider.
Assumptions	Setpoints can be provided to battery and heat pumps.
Measured and calculated variables	Energy; state of charge. Calculated variables are as defined in the respective KPIs.
Benchmark	Initially, the edge computation will run in parallel to the existing optimisation framework without providing new setpoints. This will provide an assessment of the potential for improvements in optimisation. When setpoints are applied, historical values will be used to provide an estimate of the algorithm performance
FUNCTIONAL PERFORMANCE TEST #3 AM AAWASSER	
Test name	**Functional performance test of sub-metering device**
Technical development to test	The sub-metering device developed in Task 5.2 by SmartHelio.
Objective	Evaluate the functional performance of the sub-metering device.
Scope	Two types of Smarthelio device are available. The first, a production device, is capable of measuring current, voltage and temperature of selected PV modules and uploading data values to the cloud for analysis. The second, a prototype device, computes forecasts on-device based on locally stored values. In the Am Aawasser test, the prototype device will be deployed and evaluated. In contrast, in other test sites, the production device will be used. The sub-metering device will be used to compute only PV production data in connection with forecast data being generated by a compute service on the cloud or at the edge. Load or heat forecasts will not be deployed onto the device.
Description	The sub-metering device will communicate directly with the Reengen IoT gateway that is deployed onsite. SmartHelio will provision the endpoints with the necessary token details in the hardware so that it can securely establish a connection with the Reengen gateway. It will be a push-based data export (into the Reengen gateway) from the hardware perspective. In addition, an LTE connection will also be established to the SmartHelio cloud. The connection will also be routed through SmartHelio's platform. Devices

	which are deployed within the scope of the project will push the data into SmartHelio's cloud and then a cloud based service at SmartHelio's platform's end will push the relevant information through the Reengen IoT gateway. In this case, the interface between SmartHelio and Reengen can be defined as a pure database API connect system. We can store all our results (post-edge processing) in a SQL server and then offer access to the SQL database through a read/write API to Reengen. Forecasting performance will be evaluated in accordance with the definitions in the KPI's listed in the next section. Forecasting will be conducted for day ahead and hour ahead time periods at a resolution of 15 minutes (hour ahead) and 60 minutes (day ahead). Data will be collected to enable the execution of the forecasts.
KPIs	<u>Forecasting KPI</u>: ● **KPI_FO_1**: Forecasting error
Prerequisites	Data connection must be established with the sub-metering device. Permission is required to install the sub-metering device at Am Aawasser. Data collection must be established with a cloud weather forecasting service.
Assumptions	Weather forecasts will be obtained from a cloud-based forecasting service: no weather forecasting will be conducted on-device.
Measured and calculated variables	Measured values: current, voltage, temperature. Calculated values: forecast power based on module measurements obtained from the edge device.
Benchmark	Forecasts will be compared with actual measured values of power.
FUNCTIONAL PERFORMANCE TEST #4 Am AAWASSER	
Test name	**Functional performance test for the Prosume cloud**
Technical development to test	Prosume cloud is used for settlement and smart contracts. It integrates the DLT-based community manager platform, DLT-based prosumer account platform, DSO contracting platform and the Mobile-app for interaction with the user.
Objective	Certificate the accuracy of identities, entities, data and transactions.
Scope	Local Energy Communities members and interactions.
Description	The service will evaluate several factors to formalise data or services bid/ask.
KPIs	<u>Prosume cloud KPIs:</u> ● **KPI_Pro_1**: Quantity of identities (users) of an Energy Community in a Mobile Pro ● **KPI_Pro_2**: Quantity of transactions between users members of the same community ● **KPI_Pro_3**: Ratio of successful transactions

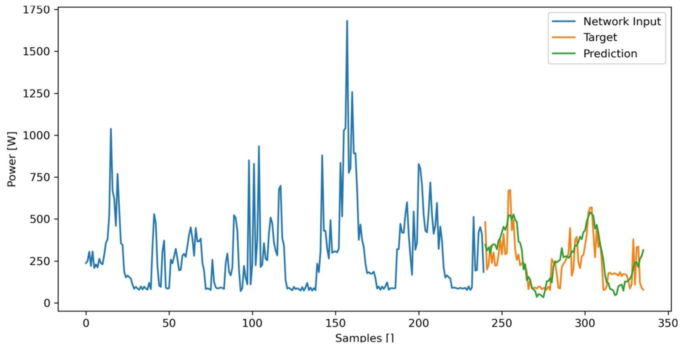
Prerequisites	• Anonymous data and transaction tracking • Opt-in / agreement from consumers. At present, the energy management system is operated centrally by the Am Aawasser site owner
Assumptions	Value capture and sharing will be virtual - no incentives will be shared in practice. The implementation of the mobile app will be virtual / in a test setting, as it will not be possible to connect the Prosume app with the existing energy management system.
Measured and calculated variables	The service will define data ownership, origin and destination, and the incentive sharing model (equally, linked to investment, linked to self-consumption...)
Benchmark	The base scenario will require auditing previous user and data interactions of energy communities currently deployed.

Forecasting verification in Am Aawasser LEC

Table 4 describes in detail the forecasting verification test in Am Aawasser.

Table 4 - Forecasting evaluation test in Am Aawasser.

FORECASTING EVALUATION IN Am AAWASSER	
Test name	**Forecasting algorithms verification and evaluation**
Developments to test	• Forecasting accuracy / Forecasting Loss
Objective	Create a forecasting accuracy for day-ahead forecasting for both the PV-Production and the electric load consumption of the (Aawasser) testing site in Switzerland.

Description	The optimisation algorithm requires the input of certain forecasted values, to be able to assume a certain production and consumption of energy of the next day. This is achieved using state of the art forecasting and algorithms to train several predictors on the production and consumption pattern of the different testing sites. A functioning prediction could look something like this:  The specific data requirements for the minimal optimisation algorithm are the PV and electric Load patterns to function properly.
KPIs	Forecasting KPI: • **KPI_FO_1**: Forecasting error
Data requirements	Data access to Load, PV and Weather Data of the Aawasser site of the last 2+ years. Time Resolution of 15 min Intervals (or smaller) for all Input and Target Values.
Required measured variables	Historical load curves (time series of energy consumption). Historical production curves.
Benchmark	Surpass the benchmark of the simple last-day-equivalent algorithm, which assumes the production and load of the upcoming day, to be the same as the one from the past day / week.

GENTE test cases in Am Aawasser LEC

This section contains all the test cases for the Am Aawasser LEC.

Test case #1 in Am Aawasser: CO_2 emissions reduction

The first test case in Am Aawasser aims to validate the environmental use case (UC2): the reduction of the CO_2 emissions in the LEC. The description of the test case is presented in Table 5.

Table 5 - CO_2 emission reduction test case in Am Aawasser.

TEST CASE #1 AM AAWASSER	
Test name	**CO_2 emissions reduction**
Developments to test	The GENTE optimizer will demonstrate the ability to reduce the CO_2 emissions of the LEC. This tool, developed by HSLU in WP5, makes decisions on flexible assets (flexible loads such as batteries, or heat storage) while taking into account the electricity prices, weather forecast and self-consumption.
Objective	Demonstration of CO_2 emissions reduction in the community through the optimisation algorithms.
Scope	The whole LEC is considered. Assets to monitored and/or managed: • PV system • Heat system • Electric vehicles • Battery storage • Smart meter
Description	The HSLU optimizer will operate and manage the energy assets in the LEC by calculating the optimal setpoints. This optimizer will be operating for a certain period of time in order to validate the use case. During the operation, the equivalent CO_2 emissions will be calculated by considering the amount of locally produced RES that is consumed and the equivalent CO_2 conversion factors indicated in the KPIs definition. These values will be compared to a baseline. It is assumed that self-consumed electricity based on local renewable energy consumption has a lower carbon intensity than electricity imported from the electricity network. The performance of the energy community will be measured against the carbon intensity (as calculated in the KPIs). The approach may also take into account distribution system losses[2], or embodied emissions when scaling up communities as an alternative to installation of new centralised carbon-based generation. The feasibility of including an approximate measure for distribution system losses will be further investigated during research. The performance of the optimiser will be compared to historical data collected from the EcoCoach platform. The optimiser will also be implemented on the Reengen gateway. However, the optimiser on the Reengen gateway will not coordinate energy resources directly.
KPIs	Energy KPIs: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC

[2] Paulino E. Labis, Rey G. Visande, Reuel C. Pallugna, Nolan D. Caliao,The contribution of renewable distributed generation in mitigating carbon dioxide emissions,Renewable and Sustainable Energy Reviews,Volume 15, Issue 9,2011,Pages 4891-4896,ISSN 364-0321,https://doi.org/10.1016/j.rser.2011.07.064.

	• **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_7**: Grid electricity usage reduction Environmental KPIs: • **KPI_ENV_1**: CO_2 emissions during operation • **KPI_ENV_2**: Reduction of CO_2 emissions
Prerequisites	• Implementation and integration of the heat forecast provided by Chalmers
Assumptions	• The EcoCoach platform will accept new setpoints from the HSLU algorithm • The self consumption level of the energy community can be enhanced beyond the level achieved previously
Measured and calculated variables	In accordance with the KPI definitions
Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period.

Test case #2 in Am Aawasser: Increase in community autarky

The second test case in Am Aawasser has as a target the validation of an energy efficiency use case (UC3c): the increase in community autarky. The test case is described in Table 6.

Table 6 - Community autarky increase test case in Am Aawasser.

TEST CASE #2 AM AAWASSER	
Test name	**Community autarky increase**
Developments to test	The GENTE optimizer will increase autarky (self consumption) of the LEC. This tool, developed by HSLU in WP5, makes decisions on flexible assets while taking into account community supply and demand characteristics.
Objective	Demonstrate an increase in self consumption / community autarky through the optimisation algorithms.
Scope	The whole LEC is considered, as defined in Test Case 1 of Am Aawasser.
Description	The HSLU optimizer will operate and manage the energy assets in the LEC by calculating the optimal setpoints. This optimizer will be operating for a certain period of time in order to validate the use case. During the operation, self consumption will be prioritised above other optimisation objectives, considering

	the amount of locally produced RES that is consumed, and its coincidence with local energy consumption. The performance of the optimiser will be compared to historical data collected from the EcoCoach platform. The optimiser will also be implemented on the Reengen gateway. However, the optimiser on the Reengen gateway will not coordinate energy resources directly.
KPIs	Energy KPIs: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_6**: Reschedulable renewable energy use • **KPI_EN_7**: Grid electricity usage reduction
Prerequisites	• Implementation and integration of the heat forecast provided by Chalmers • Implementation and integration of the PV forecast on the Smarthelio device
Assumptions	• The EcoCoach platform will accept new setpoints from the HSLU algorithm
Measured and calculated variables	As defined in the KPI's listed above.
Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The metrics will be calculated by comparing the adjusted baseline with the GENTE reporting period.

Test case #3 in Am Aawasser: Peak load management (simulated grid inputs)

The third test case in Am Aawasser is related to the grid flexibility provision service, and aims to validate the peak load management (UC1b) by the simulation of grid inputs. The test case is described in Table 7.

Table 7 - Peak load management test case in Am Aawasser.

TEST CASE #3 Am AAWASSER	
Test name	**Peak load management**
Developments to test	The ability of the LEC to provide grid services will be assessed. Specifically, the ability to support peak load management through LEC energy resource flexibility will be assessed.

<table>
<tr><td>Objective</td><td>Demonstrate that the LEC can successfully perform peak load reduction at the grid connection point in response to (simulated) requests from the grid operator.</td></tr>
<tr><td>Scope</td><td>The whole LEC is considered, as defined in Test Case 1 in Am Aawasser.</td></tr>
<tr><td>Description</td><td>A workflow is tested that includes the Prosume contracting platform, the Reengen IoT platform, the HSLU edge intelligence, and the SmartHelio submetering device. The first part of the workflow computes a baseline and establishes a contract to supply flexibility:
<table>
<tr><th>Actor</th><th>Owner (GENTE)</th><th>Actions</th></tr>
<tr><td>DSO</td><td>N/A</td><td>Sends FlexRequest, receives FlexOffer (simulated)</td></tr>
<tr><td>Contracting platform</td><td>Prosume</td><td>Receives FlexRequest, sends FlexOffer
Requests flexibility availability from LEC
Calculates planned response to request</td></tr>
<tr><td>IoT platform</td><td>Reengen</td><td>Receives flex availability / baseline request
Triggers forecast, computes baseline
Reports forecast / baseline to contracting platform</td></tr>
<tr><td>Edge intelligence</td><td>HSLU</td><td>Forecasts flex availability, baseline</td></tr>
<tr><td>Smart DER (PV)</td><td>SmartHelio</td><td>Forecasts PV</td></tr>
</table>
The second part of the workflow initiates the flexibility action:
<table>
<tr><th>Actor</th><th>Owner (GENTE)</th><th>Actions</th></tr>
<tr><td>DSO</td><td>N/A</td><td>May send additional FlexOrders if safety analysis fails (simulated)</td></tr>
<tr><td>Contracting platform</td><td>Prosume</td><td>Sends targets to LEC control platform (requirements)
Stores responses in smart contract</td></tr>
<tr><td>IoT platform</td><td>Reengen</td><td>Receives targets
Sends setpoints to controllable resources
Sends manual activation requests to contracting platform
Collects and stores responses, then reports them to the contracting platform</td></tr>
<tr><td>Edge intelligence</td><td>HSLU</td><td>Computes setpoints
Monitors response and reports to IoT platform</td></tr>
<tr><td>Smart DER (PV)</td><td>SmartHelio</td><td>Receives setpoints and reacts</td></tr>
</table>
</td></tr>
</table>

	The workflow uses historical / stored data and forecast data from the LEC. Values received from the DSO are simulated. Contracts and interactions between the end user and the mobile app will also be simulated. Set points are provided to energy resources to demonstrate that the response can be realised.
KPIs	Energy KPIs: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_6**: Reschedulable renewable energy use • **KPI_EN_7**: Grid electricity usage reduction
Prerequisites	Set points can be realised without disruption of user comfort
Assumptions	-
Measured and calculated variables	As for previous test case
Benchmark	A benchmark is calculated as part of the process.

LEC user-engagement pilot's overview

A second site in Switzerland will be included, with the intention of validating the user-engagement in a co-design process developed in GENTE. The exact site is not yet selected. It will probably be a residential complex in the LuzernSüd area.

LEC user-engagement pilot's test case

A test case to validate the user-engagement in the co-design process developed in GENTE is presented for the second Swiss site in Table 8.

Table 8 - User-engagement test case in Switzerland.

TEST CASE #1 IN SWISS SECOND SITE	
Test name	**User engagement in co-design process**
Development to test	To what extent can stakeholders (tenants, property owners, others) in a potential energy community site be involved in development of an energy community? This test case refers to WP4, task 4.2 (not a technical development).
Objective	The objective of the test case is to assess the effectiveness of the co-design approach.
Scope	A potential energy community where we implement a co-design process.
Description	A co-design process will be initiated at the chosen site, aiming to involve stakeholders, mainly tenants, in the design of the energy community and to create acceptance of participation in a ZEV (auto-consumption community). As the process of establishing an energy community requires a longer time period than the remaining GENTE project duration, it will not be possible to assess the full process.
KPIs	Social KPIs: • **KPI_SOC_4**: Overall satisfaction with co-design process • **KPI_SOC_5**: Engagement of potential users (active and passive) • **KPI_SOC_6**: Co-design participant diversity • **KPI_SOC_7**: Stakeholder quantification
Prerequisites	Access to tenants through gatekeeper, survey of tenants/participants
Measured and calculated variables	Variables calculated from surveys, mailing list, residents list, workshop attendance list, and data from site manager.

Swedish test cases

There are two demonstrators in Sweden: the HSB living lab, a building with a wide variety of energy assets to be controlled and the possibility to integrate the heating equipment management, and the Alingsås pilot, a real LEC in which the DSO is present, enabling validation of on-site grid flexibility services with real requirements from the DSO.

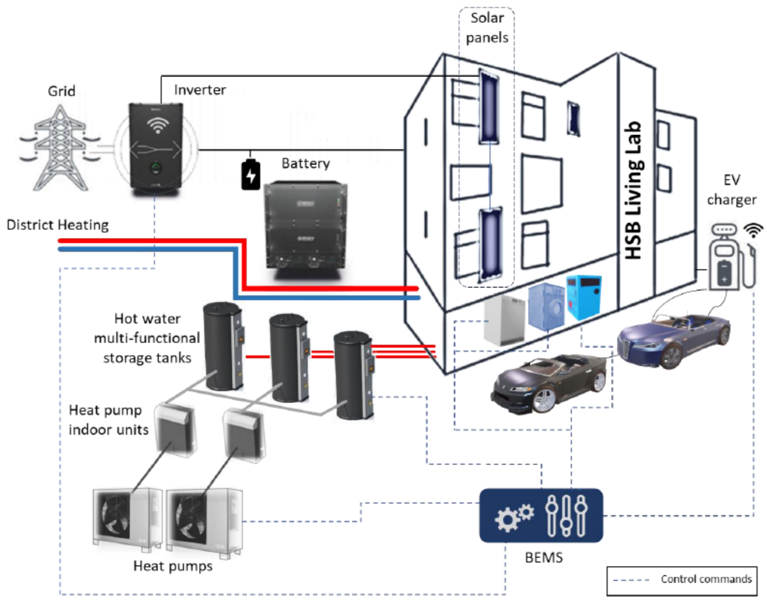
HSB Living Lab's overview

The HSB Living Lab (HSB LL) is a multi-family residential building of 29 apartments inside the Chalmers Campus. The HSB LL is a testbed for sustainable living solutions, where the living lab approach focuses on applying innovation in human-centered systems.

The HSB LL has the solar panels installed on the facade and the roof that produces 10.82 MWh of electricity annually, while the annual electricity consumption of the building is around 70.7 MWh (the daily demand ranged between 61 kWh and 259 kWh). The 18 kWp PV system is coupled with a 7.2 kWh battery, which can be charged both from the PVs and the AC grid. The PV and BESS system is connected to the AC grid via a converter provided by Ferroamp.

Several distributed energy resources (DER) and an advanced metering and sensor system are deployed at the building, which includes approximately 2000 sensors that collect various building data, for investigating the resident behavior's impact on energy consumption.

A general scheme of the installed assets is presented in Figure 12.



Figures 12 - HSB living lab general installation and energy assets scheme.

The test cases listed below are defined to test the performance of various functionalities of the HSB LL in the intelligent grid context:

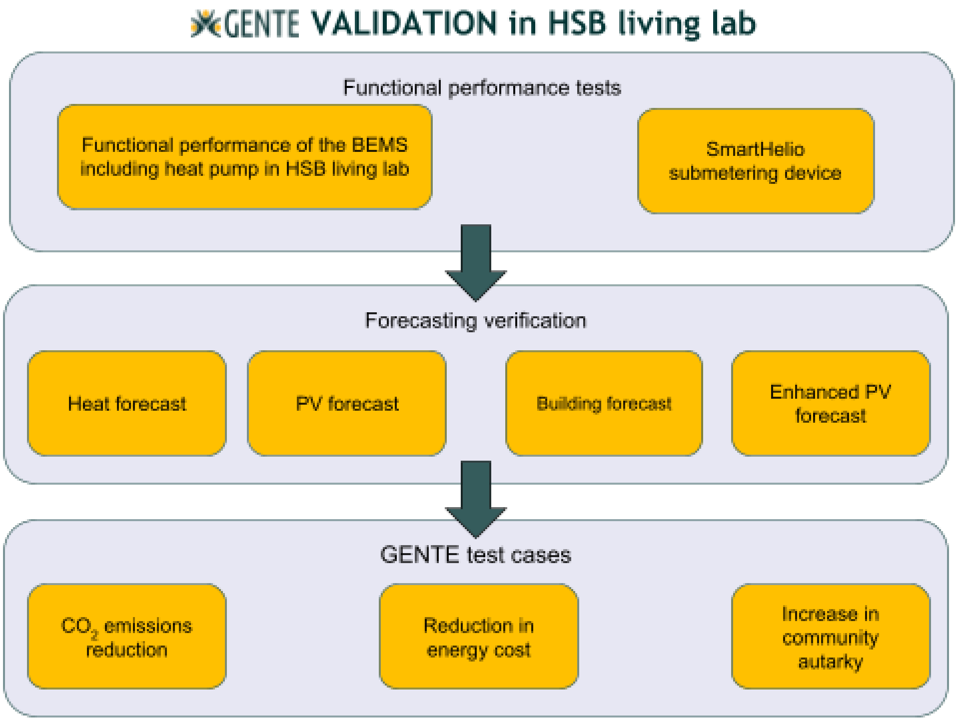


Figure 13 - GENTE validation process in HSB Living Lab.

Functional performance tests in HSB Living Lab

Table 9 describes the functional performance tests to be conducted in HSB living lab.

Table 9 - Functional performance tests in HSB Living Lab.

FUNCTIONAL PERFORMANCE TEST #1 HSB LIVING LAB	
Test name	**Functional performance test at HSB living lab**
Technical development to test	The new hardware developed or enhanced during GENTE project that will be tested is: • IoT BEMS including heat pumps • Hybrid system control for the heat pump and district heating dispatch • Reengen's gateway
Objective	Test the communication and execution of the control commands and data collection.
Scope	HSB Living Lab and its energy assets: • Heat Pump • Heat storage • Connection to the district heating • Battery storage • EV station

	• PV system • Smart meters
Description	Functional performance tests for the IoT BEMS and the Hybrid system control. It covers: 1. The commissioning and integration of the new hardware. 2. The integration and functioning of the shared signals and controller communication (between systems on local site level, and also to the Chalmers cloud/BEMS). This is done in two steps: a. Communication and control of EnergySave HeatPump from Chalmers IoT platform via EnergySave control system Webport and directly via Modbus TCP IP communication b. Communication and control of EnergySave HeatPump from Chalmers IoT platform via Reengen's gateway
KPIs	BEMS KPI: • **KPI_BEMS_3**: Delay/latency in data collection
Prerequisites	The communication interfaces must be set up. Currently, the communication is going through a web-based SCADA system called *WebPort* using Modbus TCP IP protocol. The control can also be done directly via Modbus communication. The Reengen Gateway is not installed and need to be installed and integrated to the IoT platform of Chalmers
Assumptions	Any considered assumption for the test case.
Measured and calculated variables	All the measurements that need to be monitored for the GENTE test cases, as well as the setpoints that are commanded need to be collected to calculate the previously defined KPIs. A detailed list will be elaborated once the communication system is set up.
FUNCTIONAL PERFORMANCE TEST #2 HSB LIVING LAB	
Test name	**Functional performance test of sub-metering device**
Technical development to test	The sub-metering device developed in Task 5.2 by SmartHelio.
Objective	Evaluate the functional performance of the sub-metering device.
Scope	The production device will be deployed in one PV-module of HSB living lab's PV installation. This device is capable of measuring current, voltage and temperature of selected PV modules and uploading data values to the cloud for analysis. The sub-metering device will be used to compute only PV production data in connection with forecast data being generated by a compute service on cloud.
Description	Forecasting performance will be evaluated in accordance with the definitions in the KPI's listed in the next section.

	Forecasting will be conducted for day ahead and hour ahead time periods at a resolution of 15 minutes (hour ahead) and 60 minutes (day ahead). Data will be collected to enable the execution of the forecasts.
KPIs	All forecasting KPI's, applied to the specific case of PV forecasting.
Prerequisites	Data connection must be established with the sub-metering device. Permission is required to install the sub-metering device at HSB living lab. Data collection must be established with a cloud weather forecasting service.
Assumptions	Weather forecasts will be obtained from a cloud-based forecasting service: no weather forecasting will be conducted on-device.
Measured and calculated variables	Measured values: power, current, voltage, temperature. Calculated values: forecast power for the array, based on module measurements obtained from the edge device.
Benchmark	Forecasts will be compared with actual measured values of power, current.

Forecasting algorithms verification in HSB Living Lab

Table 10 includes a description of the forecasting algorithms verification tests in the HSB living lab.

Table 10 - Forecasting evaluation test in HSB Living Lab.

FORECASTING EVALUATION IN HSB LIVING LAB	
Test name	**Forecasting algorithms verification and evaluation**
Developments to test	• PV production forecasting • Consumers' load curves forecasting • Building forecasting
Objective	Evaluate the accuracy of the forecasting algorithms.
Description	Verification of the forecasting algorithms The forecasting algorithms are validated by comparing the results computed by the algorithm with a baseline method, against actual data, or against those made by a human expert. Therefore, it is necessary to define if the comparison is quantitative or qualitative and the threshold.
KPIs	Forecasting accuracy KPI: • **KPI_FO_1**: Forecasting error
Data requirements	Period of time with historized data: one year Granularity of the data: hourly
Required measured variables	PV forecasting: solar radiation, humidity, time-factors (hour of the day, day of the week, etc). Consumer's load curves forecasting: time factors and electric consumption data.

	Heat forecasting: time factors, outdoor temperature and heat consumption data.
Benchmark	The real measurements of the PV production, heat consumption and load will be compared to the forecasted values by the algorithms.

GENTE test cases in HSB living lab

This section described the GENTE test cases in the HSB living lab, with the procedure to perform and evaluate each one.

Test case #1 in HSB living lab: CO_2 emissions reduction

The first test case in the HSB living lab consists of the validation of reduction in CO_2 emissions (UC2). The description of this test case is in Table 11.

Table 11 - CO_2 emission reduction test case in HSB Living Lab.

TEST CASE #1 HSB LIVING LAB	
Test name	**CO_2 emissions reduction**
Technical development to test	The building optimisation algorithms implemented into the IoT BEMS including the optimal management of the heat pumps.
Objective	Evaluate the reduction of CO_2 emissions by the building optimisation and more efficient operation of the heat pump.
Scope	HSB Living Lab and its energy assets: • Heat pump • Heat Storage • Connection to the district heating • Battery storage • EV station • PV system • Smart Metres
Description	The optimisation algorithms will be run during a certain period of time. The optimal dispatch between the Heat pump and the district heating that minimises the CO_2 emissions will be calculated based on a real CO_2 electricity mapping[3]. The calculated optimal dispatch will be communicated from the BEMS and commanded through the hybrid controller of EnergySave or directly via modbus TCP/IP.

[3] Electricity Maps | Reduce carbon emissions with actionable electricity data

	A baseline scenario will be generated by operating just the heat pump, and just with the district heating.
KPIs	Energy KPIs: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_3**: On-site renewable energy production in the LEC (building) • **KPI_EN_4**: On-site renewable energy consumption in the LEC (building) • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_7**: Grid electricity usage reduction Environmental KPIs: • **KPI_ENV_1**: CO_2 emissions during operation • **KPI_ENV_2**: Reduction of CO_2 emissions
Prerequisites	• Communication with the HeatPump and building control system (BEMS) properly working. • Load and PV Forecasts ready. • The building optimisation algorithm's cost function needs to be tuned to consider the CO_2 emissions reduction as an objective.
Assumptions	Not applicable.
Measured and calculated variables	The ones indicated in the KPI's description.
Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period. A digital twin of the HSB living lab (developed by R2M) consisting of a detailed building model will also be available to perform a virtual testing, and simulate a conventional scenario (without GENTE solutions) and the scenario with GENTE optimisation to evaluate the reduction in emissions.

Test case #2 in HSB living lab: Reduction in energy cost

The second test case in HSB living lab is aimed at validating the reduction in the energy cost. The description of this test case is presented in Table 12.

Table 12 - Reduction in energy cost test case in HSB Living Lab.

TEST CASE #2 HSB LIVING LAB	
Test name	**Reduction in energy cost**
Technical development to test	This test case will validate the reduction of energy cost through the BEMS of Chalmers, extended in GENTE to integrate heat pumps.

<table>
<tr><td>Objective</td><td>Evaluate the reduction of energy cost by the building optimisation and more efficient operation of the heat pump, considering spot market prices and network tariffs.</td></tr>
<tr><td>Scope</td><td>HSB Living Lab and its energy assets:
Heat pump
Heat storage
Connection to the district heating
Battery storage
EV station
PV system
Smart Metres</td></tr>
<tr><td>Description</td><td>The Building operation optimizer receives the following inputs:
Spot market prices and network tariffs
Forecast building demand
The building optimizer will calculate the optimal actuation to avoid peaks and reduce the energy cost based on the received prices. The calculated optimal setpoints will be commanded to the controlled energy assets.

The energy cost will be monitored in order to properly evaluate the prices.</td></tr>
<tr><td>KPIs</td><td><u>Energy KPIs</u>:
KPI_EN_1: Final energy consumption at building/household level
KPI_EN_2: Final energy consumption in the LEC
KPI_EN_3: On-site renewable energy production in the LEC
KPI_EN_4: On-site renewable energy consumption in the LEC
KPI_EN_5: LEC self-consumption quota
KPI_EN_6: Reschedulable renewable energy use
<u>Economic KPIs</u>:
KPI_EC_1: Energy cost savings</td></tr>
<tr><td>Prerequisites</td><td>Communication with the HeatPump and building control system (BEMS) properly working.
Load and PV Forecasts ready.
The building optimisation algorithm’s cost function needs to be tuned to consider the energy cost reduction as an objective.</td></tr>
<tr><td>Assumptions</td><td></td></tr>
<tr><td>Measured and calculated variables</td><td>All the variables indicated in the KPI definition.</td></tr>
<tr><td>Benchmark</td><td>A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period.</td></tr>
</table>

	A digital twin of the HSB living lab (developed by R2M) consisting of a detailed building model will also be available to perform a virtual testing, and simulate a conventional scenario (without GENTE solutions) and the scenario with GENTE optimisation to evaluate the reduction in energy cost.

Test case #3 in HSB living lab: Autarky increase

Another use case for the HSB living lab is the autarky increase in the building, so a fourth test case is included with this aim, which is described in Table 13.

Table 13 - Building optimisation for energy efficiency test case in HSB Living Lab.

TEST CASE #3 HSB LIVING LAB	
Test name	**Building optimisation for Autarky increase**
Technical development to test	The building optimisation algorithms developed within GENTE to optimally manage the energy assets at HSB living lab, including the heat pump.
Objective	This test case will validate the autarky increase (self-consumption increase) at HSB living lab.
Scope	HSB Living Lab and its energy assets: • Heat pump • Heat storage • Connection to the district heating • Battery storage • EV station • PV system • Smart Metres
Description	The building optimizer will calculate the optimal actuation to increase self consumption. Different scenarios will be demonstrated depending on electricity autarky or heat autarky. The calculated optimal setpoints will be commanded to the controlled energy assets. The electricity and heat import will be monitored in order to properly evaluate the autarky level.
KPIs	Energy KPIs: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_6**: Reschedulable renewable energy use • **KPI_EN_7**: Grid electricity usage reduction
Prerequisites	• Communication with the HeatPump and building control system (BEMS) properly working.

	• Load and PV Forecasts ready. • The building optimisation algorithm's autarky function needs to be tuned to consider the energy cost reduction as an objective.
Assumptions	The autarky can be considered both from an electricity or heat perspective, the test case will evaluate both.
Measured and calculated variables	All the variables indicated in the KPI definition.
Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period. A digital twin of the HSB living lab (developed by R2M) consisting of a detailed building model will also be available to perform a virtual testing, and simulate a conventional scenario (without GENTE solutions) and the scenario with GENTE optimisation to evaluate the increase in autarky.

Alingsås pilot overview

The Alingsås pilot will consist of a building connected to a district heating network, in which the heat pump plug-in module produced by EnergySave will be installed. This module allows the heating demand of the building to be covered by either the district heating or the installed heat pump.

The exact building in which this module will be installed and that will set up the pilot is still in the selection process among 6 buildings that comply with the required conditions to be used as a demo-site. The following aspects are being evaluated to choose the most convenient one:

- Control system architecture and specification, HP-system, building system, GENTE overall system.
- Trying to have at least one commercial building in the LEC.
- Permits from authorities to get approved.

This pilot will be used to demonstrate how to develop a sustainable energy society through cooperation between:

- The local utility company (Alingsås Energi AB).
- The heat pump system provider (Energy Save AB).
- Property energy consumers and prosumers (Alingsåshem AB).
- The GENTE top level control system (Chalmers).

Hybrid heat pumps, which use locally produced renewable electricity and electricity from the grid, are used to reduce the total energy requirement of the regional transmission grid. These hybrid heat pumps select the electricity source and load control with data from the local grid company and the LEC upper level control platform.

The load control and forecasting system leads to reducing the total emissions of CO_2 locally in Alingsås and to making the use of both energy and power leads more efficient in the local electricity grid and the regional electricity grid.

The mentioned goals will be assessed according to the following tests presented in Figure 14:

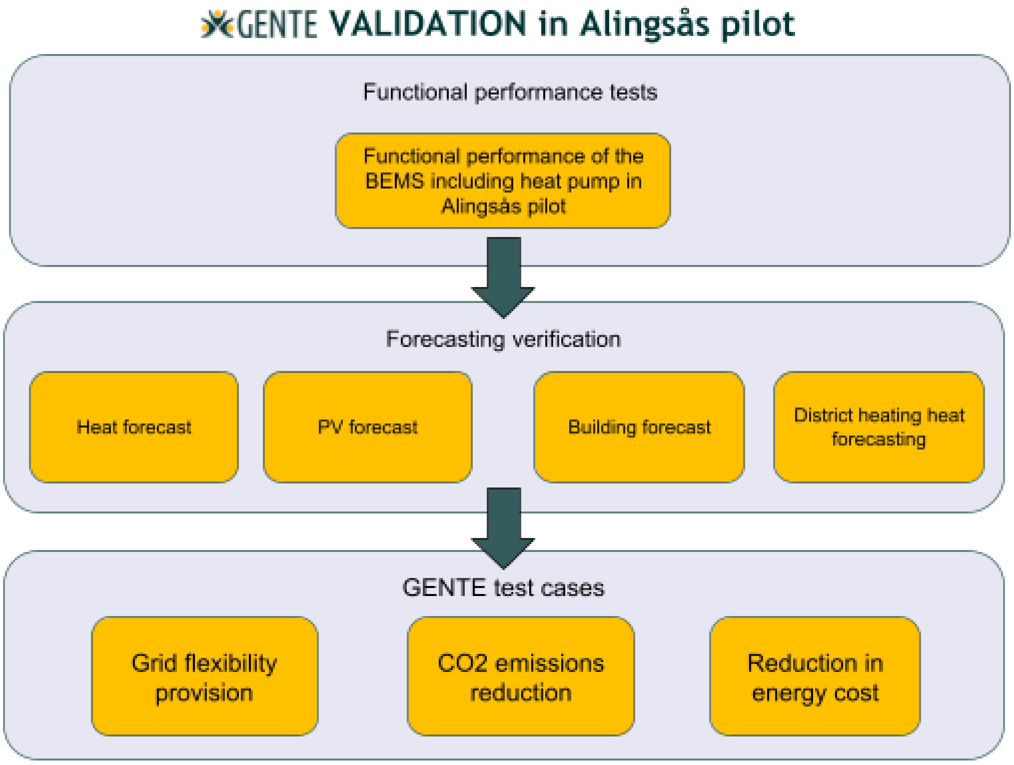


Figure 14 - GENTE validation process in Alingsås pilot.

Functional performance tests in Alingsås pilot

The functional performance test to be carried out in Alingsås pilot is described in Table 14.

Table 14 - Functional performance test in Alingsås pilot.

FUNCTIONAL PERFORMANCE TESTS IN ALINGSÅS PILOT	
Test name	**Functional performance test of the monitoring, communication and control architecture at Alingsås pilot**
Technical development to test	This test considers the monitoring, communication and control architecture at the Alingsås pilot. This includes the new hardware developed or enhanced during GENTE project that will be tested is: • IoT BEMS including heat pumps from Chalmers (cloud) • Hybrid system control for the heat pump and district heating dispatch This new hardware will be integrated in the already existing monitoring and control architecture in the pilot.

Objective	Functional performance tests for the IoT BEMS and the Hybrid system control covers: 1. The commissioning and integration of the new hardware. 2. The integration and functioning of the shared signals and controller communication (between systems on local site level, and also to the Chalmers cloud/BEMS). This is divided in three steps: a. Communication and control of EnergySave Heat pump from Chalmers IoT platform via EnergySave control system *Loggamera* b. Communication from AlingåsEnergy to Chalmers IoT platform c. Communication from Alingås Hem to Chalmers IoT platform
Scope	Alingsås pilot monitoring, communication and control system, and its energy assets: • Heat pump • Heat storage • Connection to the district heating • Smart meters
Description	Verify the setup, communication and commissioning of the IoT BEMS and the Hybrid system control in the monitoring and operational architecture of the pilot. Once the details of the final system integration are ready, a detailed description of the requirements to be tested for the integration verification will be elaborated.
Prerequisites	The hardware needs to be deployed and the communication between the new items and the rest of the system ready for testing.
Measured and calculated variables	All the variables that are read and written by the two systems (IoT BEMS and Hybrid control system) need to be registered and accessible.

Forecasting verification in Alingsås pilot

The forecasting algorithms to be run in Alingsås pilot will be verified according to the test described in Table 15.

Table 15 - Forecasting evaluation test in Alingsås pilot.

FORECASTING EVALUATION IN ALINGSÅS PILOT	
Test name	**Forecasting algorithms verification and evaluation**
Developments to test	• Consumers' load curve forecasting • PV forecast • District heating heat forecast
Objective	Evaluate the accuracy of the forecasting algorithms.
Description	Verification of the forecasting algorithms

	The forecasting algorithms are validated by comparing the results computed by the algorithm with a baseline method, against actual data, or against those made by a human expert. Therefore, it is necessary to define if the comparison is quantitative or qualitative and the threshold.
KPIs	Forecasting accuracy KPIs: • **KPI_FO_1**: Forecasting error
Data requirements	Period of time with historized data: one year Granularity of the data: Hourly data
Required measured variables	PV forecasting: solar radiation, humidity and time factors. Consumer's load curves forecasting: electric consumption data and time factors. Heat forecasting: heat consumption data, outdoor temperature and time factors.
Benchmark	The real measurements of the PV production, heat consumption and load will be compared to the forecasted values by the algorithms.

GENTE test cases in Alingsås pilot

This section described the test cases to be conducted in Alingsås pilot.

Test case #1 Alingsås pilot: Grid flexibility provision

Table 16 described the first test case in Alingsås pilot for grid flexibility provision (UC1).

Table 16 - Grid flexibility provision test case in Alingsås pilot.

TEST CASE #1 ALINGSÅS PILOT	
Test name	**Grid flexibility provision**
Technical development to test	The service that provides grid flexibility, which is based on the IoT BEMS including the heat pump system developed by Chalmers that manages the energy assets available on-site (GENTE top level control system). This solution also relies on the operation of the hybrid system control of Energy Save that calculates the optimal dispatch to cover the heating demand between the district heating and the heat pump.
Objective	Validate the provision of local flexibility by the system based on the requirement signal sent by Alingsås Energi. Through load control with data from the local grid company and the LEC upper level control platform, heat pumps are used so that they increase the use of renewable electricity and reduce the total need for power from the regional transmission grid. This can also be used for objectives such as peak shaving, flexibility and balancing services.

Scope	The whole Alingsås pilot is considered. This test includes the coordination between these partners: ▪ The local utility company or DSO (Alingsås Energi AB) ▪ The heat pump system provider (Energy Save AB) ▪ Property energy consumers and prosumers (Alingsåshem AB) ▪ The GENTE top level control system (Chalmers)
Description	This test will validate if the required flexibility requested by the DSO can be provided. A signal will be received from the DSO with a flexibility request when a certain predefined percentage of the subscription capacity has been reached, this could be both from electricity or the heat system. The GENTE top level control system will be operating, as well as the hybrid control system of the heat pump. A simplified on/off control will be applied for different durations (1 h, 2h 3h etc.) in order to fulfil the flexibility request by the DSO. Feedback from room sensors will be used to evaluate comfort and check how far this approach can go before creating discomfort. Reinforcement learning to estimate the flexibility duration and amount.
KPIs	<u>Energy and flexibility related KPIs</u>: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_6**: Reschedulable renewable energy use • **KPI_EN_7**: Grid electricity usage reduction <u>Comfort KPIs</u>: • **KPI_CO_1**: Thermal comfort level • **KPI_CO_2**: Thermal discomfort duration
Prerequisites	• Communication with the heat pump system, the DSO, the real estate owner, and temperature sensors from the buildings.
Measured and calculated variables	Energy and flexibility related measured and calculated variables: • Final energy consumption in the LEC, disaggregated into the electric consumption of the grid (for the heat pump) and the district heating consumption. • The flexibility requests information (% that is requested, time at which is requested, the incentives associated with it). Comfort related measurements: • Indoor temperature in the rooms from the buildings.
Benchmark	The flexibility provision will be measured as the reduction of the heat pump consumption with respect to the consumption at the moment in which the flexibility request is conducted.

Test case #2 - Alingsås pilot: CO_2 emissions reduction

The test case of CO_2 emission reduction (UC2) in the Alingsås pilot is described in Table 17.

Table 17 - LEC optimisation for CO_2 emissions reduction test case in Alingsås pilot.

TEST CASE #2 ALINGSÅS PILOT	
Test name	**CO_2 emissions reduction**
Technical development to test	The GENTE LEC optimizer with the target of CO_2 emissions reduction (Chalmers optimizer / BEMS), together with the hybrid system controller of Energy Save.
Objective	Evaluate the local CO_2 emissions reduction in Alingsås through load control and forecasts.
Scope	The Alingsås pilot, with all its energy assets: • Heat pump • Heat storage • Connection to the district heating
Description	The optimisation algorithms will be run during a certain period of time. The optimal dispatch between the heat pump and the district heating that minimises the CO_2 emissions will be calculated based on a real CO_2 electricity mapping[4]. The calculated optimal dispatch will be communicated from the BEMS and commanded through the hybrid controller of EnergySave. A baseline scenario will be generated by operating just the heat pump, or just with the district heating.
KPIs	Energy KPIs: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_7**: Grid electricity usage reduction Environmental KPIs: • **KPI_ENV_1**: CO_2 emissions during operation • **KPI_ENV_2**: Reduction of CO_2 emissions
Prerequisites	• Communication with the heat pump and building control system (BEMS) properly working. • Load and PV Forecasts ready. • The building optimisation algorithm's cost function needs to be tuned to consider the CO_2 emissions reduction as an objective.
Assumptions	Not applicable.

[4] Electricity Maps | Reduce carbon emissions with actionable electricity data

Measured and calculated variables	The ones indicated in the KPI's description.
Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period.

Test case #3 - Alingsås pilot: Energy cost minimisation

Table 18 describes the test case of energy cost minimisation (UC3a) in Alingsås pilot.

Table 18 - LEC optimisation for cost minimisation test case in Alingsås pilot.

TEST CASE #3 ALINGSÅS PILOT	
Test name	**Energy cost minimisation**
Technical development to test	The GENTE LEC optimizer with the target of cost minimisation (Chalmers optimizer / BEMS), together with the hybrid system controller of Energy Save.
Objective	Evaluate the cost reduction in Alingsås through load control and forecasts.
Scope	The Alingsås pilot, with all its energy assets: • Heat pump • Heat storage • Connection to the district heating
Description	The Building operation optimizer receives the following inputs: • Spot market prices and network tariffs • Forecast building and PV demand The Building optimizer will calculate the optimal actuation to avoid peaks and reduce the energy cost based on the received prices. The calculated optimal setpoints will be commanded to the controlled energy assets. The energy cost will be monitored in order to properly evaluate the prices. Two phases will be considered for this test case. • First phase. Only spot market prices and network tariffs are considered. • Second phase. The local flexibility provision incentives are also considered. In this case, the flexibility provision requests sent by the DSO (Test case #1 in Alingsås pilot) will also be tackled. The incentives received for the flexibility provision are also computed for the energy cost reduction.
KPIs	Energy KPIs: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC

	• **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_6**: Reschedulable renewable energy use • **KPI_EN_7**: Grid electricity usage reduction • **KPI_EN_8**: Energy savings triggered by the project Economic KPIs: • **KPI_EC_1**: Energy cost savings
Prerequisites	• Communication with the heat pump and building control system (BEMS) properly working. • Load and PV Forecasts ready. • The building optimisation algorithm's cost function needs to be tuned to consider the energy cost reduction as an objective. • The Test case #1 of Alingsås pilots need to have been conducted before for the second phase considered in the description.
Assumptions	Not applicable.
Measured and calculated variables	All the variables indicated in the KPI's definition. Additional ones: the flexibility requests information (% that is requested, time at which is requested, the incentives associated with it).
Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period.

Turkish test cases

There are two Turkish pilots in two islands. Each one is described below.

Troya Cooperative overview: Çanakkale city

Troya cooperative is a residential energy community located in Çanakkale City. The cooperative is equipped with large PV installations and heat pumps.

Figures 15, 16, 17 - TROYA LEC in Çanakkale city, PV installation and heat pumps.

Solar PV system is installed on the roof of 4 of the 10 residences to be determined in Çanakkale. The total installed power is 20 kWp. The residences belong to the members of TROYA Renewable Energy Cooperative and are at different addresses. Moreover, two of the residences have heat pumps.

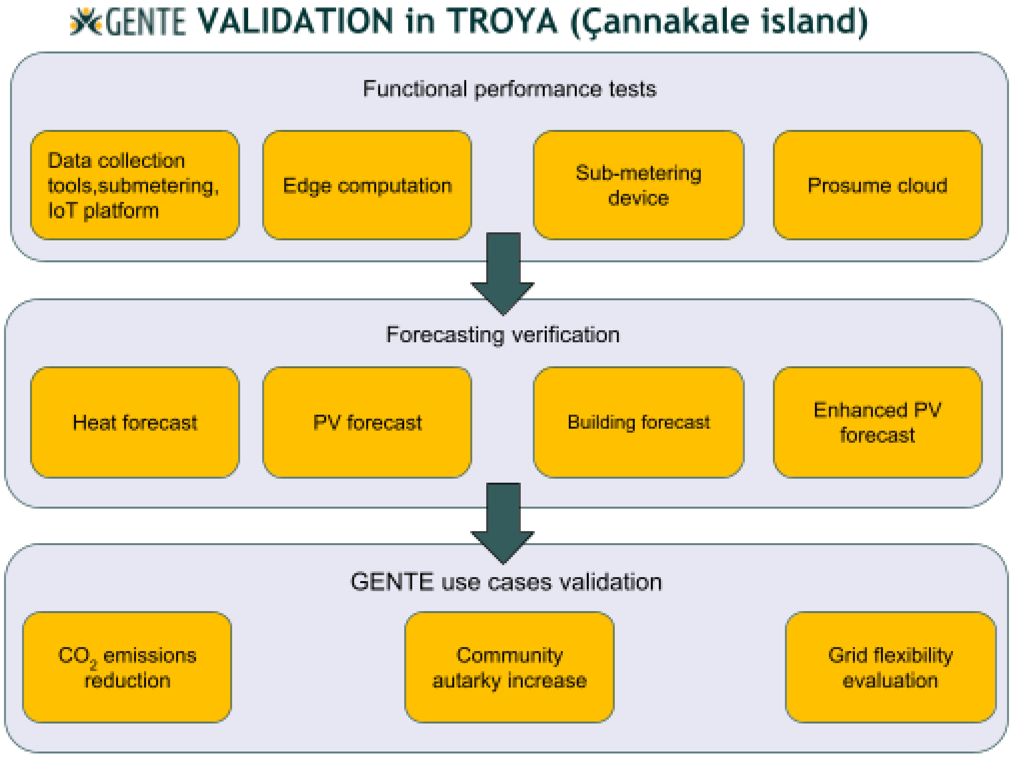


Figure 18 - GENTE validation process in TROYA cooperative in Çanakkale island.

Functional performance tests in Troya Cooperative

The functional performance tests for Troya cooperative in Çanakkale island are described in Table 19.

Table 19 - Functional performance test in Troya cooperative.

FUNCTIONAL PERFORMANCE TEST #1 TROYA (ÇANAKKALE ISLAND)	
Test name	**Functional performance test for the data collection tools, submetering, IoT platform**
Developments to test	Data collection will take place using Reengen gateways and storage will take place on the Reengen IoT Platform. Stored data will be used for optimisation, data analytics and identity management.
Objective	Demonstrate that data can be collected, consolidated and made available to the upstream processes on optimisation, data analytics, and contracting platforms.
Scope	The whole LEC is considered. Assets to monitored and/or managed: • Smart thermostats • PV arrays • Controllable heating systems in the households • Smart meters

Description	The functional performance test will be conducted on data collection tools, submetering, and IoT platforms. The results of the test will show that the data can be collected, consolidated, and made available to the upstream processes such as optimisation, data analytics, and Contracting Platforms. The test considers the whole LEC, including smart thermostats, PV arrays, controllable heating systems, and smart meters, which will be monitored and/or managed. The Reengen gateways will be responsible for collecting and storing the data on the Reengen IoT Platform, which can be used for optimisation, data analytics, and identity management. To extract data from the platform, necessary connections such as Restful API should be established. The Reengen IoT Platform will receive the request for baseline and availability requests and then trigger and report forecasts, as well as computing the baseline to the contracting platform.
KPIs	Energy KPIs: ● **KPI_EN_1**: Final energy consumption at building/household level ● **KPI_EN_3**: On-site renewable energy production in the LEC ● **KPI_EN_4**: On-site renewable energy consumption in the LEC
Prerequisites	The IoT gateways need to be installed and defined (Register mapping) on our platform. For data extraction from the platform, necessary connections (Restful API) should be done.
Assumptions	Not applicable.
Measured and calculated variables	● Electricity production, by source (PV) ● Electricity consumption, by consumer type ● Electricity import/export ● Heat production, by producer type (heat pump/ immersion heater) ● Heat storage temperatures and flow ● Heat consumption by end-usage and flexibility
Benchmark	● Data will be available at the resolution required for forecasting and community optimisation.
FUNCTIONAL PERFORMANCE TEST #2 TROYA (ÇANAKKALE ISLAND)	
Test name	**Functional performance test for edge computation**
Developments to test	Edge-computation capable gateways and optimizers will be transmitting and extracting data from the Reengen IoT platform. It will gather high-quality data, incorporating forecasting algorithms, optimisation and control strategies for LECs and associated services (e.g., peak load control by heat-pumps/buildings) by LECs. Capabilities of Reengen IoT gateways can be summarised as: ● Receiving requests and boundary conditions for optimisation ● Conducting energy resource forecasts ● Calculate and determining setpoints ● Pushing setpoints to energy resources ● Verifying device shift to setpoint

Objective	Demonstrate that relevant computation for forecasting and optimisation are matching or close to actual data. Successful data integration into the IoT platform.
Scope	The whole LEC is considered. Assets to monitored and/or managed: ● PV system ● Heat pump ● Battery storage ● Smart meters
Description	The functional performance test for edge computation involves the use of gateways and optimizers that are capable of edge computation. These gateways and optimizers will be responsible for transmitting and extracting data from the Reengen IoT platform. The test aims to gather high-quality data by incorporating forecasting algorithms, optimisation, and control strategies for LECs and their associated services. The test covers the entire LEC, ensuring that all components of the LEC are considered.
KPIs	<u>Energy Performance Indıcators:</u> ● **KPI_EN_1:** Final energy consumption at building/household level ● **KPI_EN_2:** Final energy consumption in the LEC ● **KPI_EN_4:** On-site renewable energy consumption in the LEC <u>Hardware/ICT Key Indıcators:</u> ● **KPI_IoT_1**: Algorithm and forecast execution performance ● **KPI_Edge_1**: Transferability of optimisation algorithm
Prerequisites	The IoT gateways need to be installed and defined (Register mapping) on our platform. Forecasting and optimisation algorithms that will run on IoT gateways should be installed.
Assumptions	Not applicable.
Measured and calculated variables	The ones considered in the KPI definition.
Benchmark	Not applicable.
FUNCTIONAL PERFORMANCE TEST #3 TROYA (ÇANAKKALE ISLAND)	
Test name	**Functional performance test for sub-meter device**
Technical development to test	The sub-metering device developed in Task 5.2 by SmartHelio.
Objective	Evaluate the functional performance of the sub-metering device.
Scope	The Smart Helio production device will be deployed in one PV-module of TROYA cooperative PV installation. This device is capable of measuring current, voltage and temperature of selected PV modules and uploading data values to the cloud for analysis. The sub-metering device will be used to compute only PV production data in connection with a forecast data being generated by a compute service on cloud

Description	An LTE connection will be established to the SmartHelio cloud. Forecasting performance will be evaluated in accordance with the definitions in the KPI's listed in the next section. Forecasting will be conducted for day ahead and hour ahead time periods at a resolution of 15 minutes (hour ahead) and 60 minutes (day ahead). Data will be collected to enable the execution of the forecasts.
KPIs	All forecasting KPI's, applied to the specific case of PV forecasting.
Prerequisites	Data connection must be established with the sub-metering device. Data collection must be established with a cloud weather forecasting service.
Assumptions	Weather forecasts will be obtained from a cloud-based forecasting service: no weather forecasting will be conducted on-device.
Measured and calculated variables	Measured values: power, current, voltage, temperature. Calculated values: forecast powerfor the array, based on module measurements obtained from the edge device.
Benchmark	Forecasts will be compared with actual measured values of power, current.
FUNCTIONAL PERFORMANCE TEST #4 TROYA (ÇANAKKALE ISLAND)	
Test name	**Functional performance test for the Prosume cloud**
Technical development to test	Prosume cloud is used for settlement and smart contracts. It integrates the DLT-based community manager platform, DLT-based prosumer account platform, DSO contracting platform and the Mobile-app for interaction with the user.
Objective	Certificate the veracity of identities, entities, data and transactions.
Scope	Local Energy Communities members and interactions.
Description	The service will evaluate several factors to formalise data or services bid/ask.
KPIs	<u>Prosume cloud KPIs:</u> • **KPI_Pro_1**: Quantity of identities (users) of an Energy Community in a Mobile Pro • **KPI_Pro_2**: Quantity of transactions between users members of the same community • **KPI_Pro_3**: Ratio of successful transactions
Prerequisites	• Anonymous data and transaction tracking
Assumptions	None.
Measured and calculated variables	The service will define data ownership, origin and destination, and the incentive sharing model (equally, linked to investment, linked to self-consumption...)
Benchmark	The base scenario will require auditing previous user and data interactions of energy communities currently deployed.

Forecasting verification in Troya Cooperative

Table 20 described the verification of forecasting in Çanakkale island.

Table 20 - Forecasting evaluation test in Troya cooperative (Çanakkale island).

FORECASTING EVALUATION IN TROYA (ÇANAKKALE ISLAND)	
Test name	**Forecasting algorithms verification and evaluation**
Developments to test	• PV production forecasting • Consumers' load curves forecasting • Building forecasting
Objective	Evaluate the accuracy of the forecasting algorithms.
Description	The forecasting algorithms are validated by comparing the results computed by the algorithm with a baseline method, against actual data. Therefore, it is necessary to define if the comparison is quantitative or qualitative and the threshold.
KPIs	Forecasting accuracy KPI: • **KPI_FO_1:** Forecasting error
Data requirements	Period of time with historized data: one year Granularity of the data: hourly
Required measured variables	PV forecasting: PV production and meteorological variables. Consumer's load curves forecasting: electric consumption data. Heat forecasting: thermal consumption data.
Benchmark	The real measurements of the Pv production, heat consumption and load will be compared to the forecasted values by the algorithms.

GENTE test cases in Troya Cooperative

This section describes the test cases for the TROYA cooperative in Çanakkale island.

Test case #1 TROYA Cooperative (Çanakkale island): CO_2 emissions reduction

The test case for CO_2 emissions reduction (UC2) in the Çanakkale island is described in Table 21.

Table 21 - CO_2 emissions reduction test case in Troya cooperative (Çanakkale island).

TEST CASE #1 TROYA (ÇANAKKALE ISLAND)	
Test name	**LEC optimisation for CO_2 emissions reduction**

Developments to test	The GENTE optimizer that aims to reduce the CO_2 emissions of the LEC. This tool, developed by HSLU in WP5, makes decisions on flexible assets while taking into account the electricity prices, weather forecast and self-consumption. The tool is deployed on-site, and Reengen's IoT platform enables integrating distributed assets and data sources.
Objective	Demonstration of CO_2 emissions reduction in the community through the optimisation algorithms.
Scope	The TROYA (Çanakkale island) energy assets monitored and controlled: • Smart thermostats • PV modules • Heat pumps • Smart metres
Description	The Functional performance test for LEC optimisation aims to reduce CO_2 emissions by deploying green LECs as an alternative to fossil-fuel-based power generation. The test is designed to bring intelligence to the grid edge, enabling decentralised control of green LECs using data analytics technology. The primary goal of this test is to achieve a reduction in CO_2 emissions, and this will be accomplished through the deployment of green LECs. These green LECs will be controlled using data analytics technology, which will enable intelligent and decentralised control at the grid edge. By deploying green LECs and reducing the reliance on fossil-fuel-based power generation, this test aims to achieve a significant reduction in CO_2 emissions.
KPIs	Energy KPIs: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_7**: Grid electricity usage reduction Environmental KPIs: • **KPI_ENV_1**: CO_2 emissions during operation • **KPI_ENV_2**: Reduction of CO_2 emissions
Prerequisites	The functional performance tests should have been accomplished successfully. Sufficient data must be collected by Reengen to allow adaptation of the optimisation algorithm to local conditions A full site specification should be made available
Assumptions	Any considered assumption for the test case.
Measured and calculated variables	In accordance with the KPI definition.
Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions

	(i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period.

Test case #2 TROYA Cooperative (Çanakkale island): Community autarky increase

Table 22 describes the test case related to the community autarky increase (UC3c) in Çanakkale island.

Table 22 - Community autarky increase test case in Troya cooperative (Çanakkale island).

TEST CASE #2 TROYA (ÇANAKKALE ISLAND)	
Test name	**Community autarky increase**
Technical development to test	The overall system is aimed to serve increasing autarky of the LEC. With the integration of IoT gateways to the sub-metering devices, necessary analysis, and device management for flexible assets (heat pumps) can be set and established by considering solar production.
Objective	Demonstration of community autarky increase in the community through the optimisation algorithms.
Scope	The TROYA (Çanakkale island) energy assets monitored and controlled: ● Smart thermostats ● PV modules ● Heat pumps ● Smart metres
Description	The IoT gateways will collect consumption and forecast data from sub-metering devices and SmartHelio clouds, and transmit them into the Reengen IoT platform, where other project partners such as HSLU can gather those data and use them in device management and optimisation purposes. With this way, Reengen platform and IoT gateways will act as a bridge between devices and platforms for better management and autarky. The objective is to increase the community autarky through the self-consumption maximisation coming from renewable sources.
KPIs	Energy KPIs: ● **KPI_EN_1**: Final energy consumption at building/household level ● **KPI_EN_2**: Final energy consumption in the LEC ● **KPI_EN_3**: On-site renewable energy production in the LEC ● **KPI_EN_4**: On-site renewable energy consumption in the LEC ● **KPI_EN_5**: LEC self-consumption quota ● **KPI_EN_6**: Reschedulable renewable energy use ● **KPI_EN_7**: Grid electricity usage reduction
Prerequisites	The functional performance tests should have been accomplished successfully.
Assumptions	Not applicable.
Measured and calculated variables	As defined in the KPI's listed above.

Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period.

Test case #3 TROYA Cooperative (Çanakkale island): Grid flexibility availability evaluation

Table 23 reflects the test description for an evaluation of the grid flexibility provision.

Table 23 - Grid flexibility availability evaluation test case in Troya cooperative.

TEST CASE #2 TROYA (ÇANAKKALE ISLAND)	
Test name	**Grid flexibility availability evaluation**
Developments to test	The GENTE optimizer that aims to provide flexibility of the LEC. This tool, developed by HSLU in WP5, makes decisions on flexible assets (flexible loads such as EV charging, or electric/heat storage) while taking into account the electricity prices, weather forecast and self-consumption. The tool is deployed on-site, and Reengen's IoT platform enables integrating distributed assets and data sources.
Objective	Evaluation of the possible flexibility provision that the LEC is able to comply for.
Scope	The whole LEC is considered. Assets to monitored and/or managed: • PV system • Hydro power • Heat pump • Heat storage • EV station • Battery storage • Smart meter
Description	A simulation of peak load management and self consumption optimisation will be used to demonstrate the feasibility of providing grid services in this test site.
KPIs	<u>Energy KPIs:</u> • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_6**: Reschedulable renewable energy use • **KPI_EN_7**: Grid electricity usage reduction
Prerequisites	Set points can be realised without disruption of user comfort.
Assumptions	Any considered assumption for the test case.

Measured and calculated variables	• Electricity production, by source (PV) • Electricity consumption, by consumer type • Electricity import/export • Heat production, by producer type (heat pump/ immersion heater) • Heat storage temperatures and flow • Heat consumption by end-usage and flexibility
Benchmark	A benchmark is calculated as part of the process.

User-engagement assessment through Mobile-App interactions

An assessment of the user-engagement level through Prosume's Mobile-App will be performed according to the test description provided in Table 24.

Table 24 - User-engagement evaluation in Troya cooperative.

Social assessment	
Test name	**User-engagement (through mobile app interaction)**
Responsible partners	Prosume
Technical development to test	• GENTE's One-Stop-Shop as a Mobile-First app with powerful metrics, personal energy management and best practices awarding system developed in Task 4.4. • DLT-based community manager platform • DSO contracting platform • DLT-based prosumer account platform
Objective	Measuring the number of interactions between entities (energy assets) and identities (users).
Scope	User of the Local Energy Community.
Test-site	The mobile app should be used by any energy community that requires this user engagement layer, mainly the ones that are being developed or are open to integrate new members.
Description	Establish rankings between most efficient communities (federation of communities approach) and most efficient users of each community. Facilitate the engagement of new members sending specific invitations to users that asks to be part of a specific community
KPIs	<u>End user engagement related KPIs:</u> • **KPI_SOC_1**: Quantity of identities (users) • **KPI_SOC_2**: Interactions of each user with the Mobile app • **KPI_SOC_3**: Ratio of active and non-active number of users <u>Functional performance KPIs:</u>

	• **KPI_Pro_2**: Quantity of transactions between users members of the same community • **KPI_Pro_3**: Ratio of successful transactions
Prerequisites	• Metering data from all energy assets involved in a community • Acceptance of Terms and Conditions, already defined, and acceptance of KYC policy to formalise transactions between users
Assumptions	-
Measured and calculated variables	Energy data coming from field devices such as PV production, energy consumption, energy used by batteries and heat pumps…
Benchmark	The baseline scenario will be defined based on energy consumption historical data of each demo-site or using real data from the communities already established that are using some kind of EMS.

Troya Cooperative island LEC overview: Gökçeada island

The TROYA cooperative island energy community is an energy community on the island of Gökçeada, which is also connected to Çanakkale. This energy community is suitable for the demonstration of community federations. It is expected to be formally established in early 2023, so it is still under development.

Figures 19, 20 - TROYA LEC in Gökçeada island, Overview and PV installation.

There are 6 residences on the island, one belongs to the public administration, and another has a solar PV installation with a power of 3 kWp, determined at different addresses. Other residences will also install solar PV by monitoring their energy consumption during the project period.
The possible use cases of this pilot project could be:

- Solar energy and consumption monitoring
- Smart heat pump control via smart thermostats
- Flexible load control via smart plugs

The summary of the validation process that will be conducted in Gökçeada island is reflected in Figure 21.

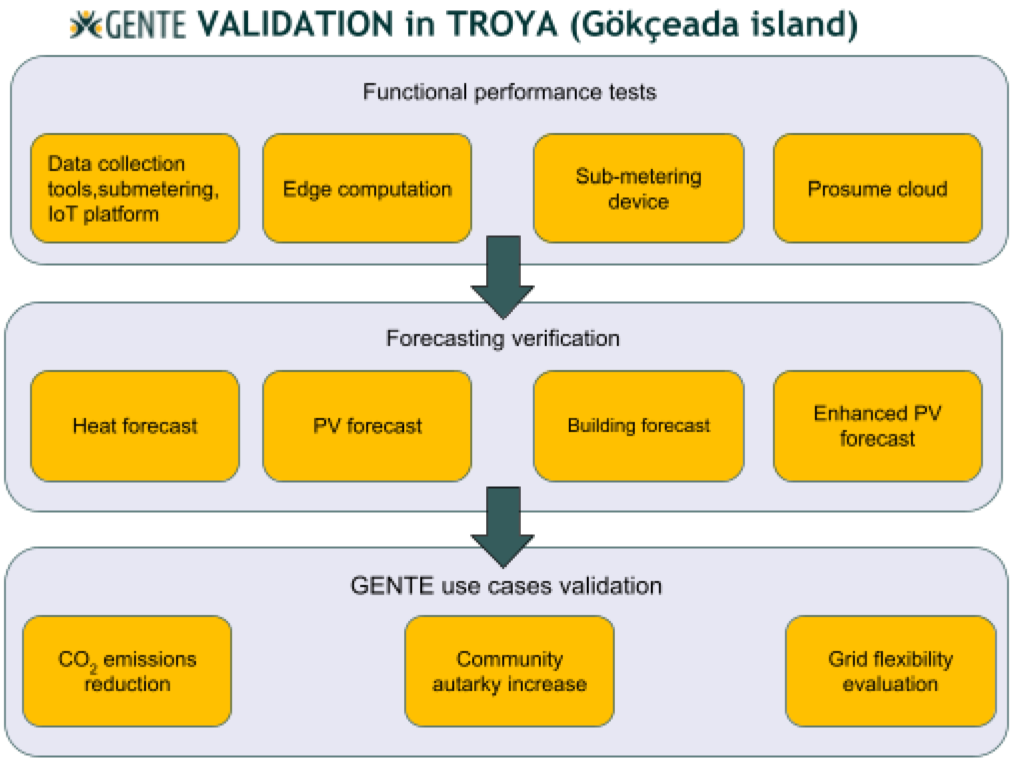


Figure 21 - GENTE validation process in TROYA cooperative in Gökçeada island.

Functional Performance Troya Cooperative island LEC

The functional performance tests for Troya cooperative in Gökçeada island are described in Table 25.

Table 25 - Functional performance test in Troya cooperative.

FUNCTIONAL PERFORMANCE TEST #1 TROYA (GÖKÇEADA ISLAND)	
Test name	**Functional performance test for the data collection tools, submetering, IoT platform**
Developments to test	Healthy data collection from Reengen gateways and its storage will take place on the Reengen IoT Platform. Also, stored data will be used for optimisation, data analytics and identity management.
Objective	Demonstrate that data can be collected, consolidated and made available to the upstream processes on optimisation, data analytics, and Contracting Platforms.
Scope	The whole LEC is considered. Assets to monitored and/or managed: • Smart thermostats • PV arrays • Controllable heating systems in the households • Smart meters

Description	The functional performance test will be conducted on data collection tools, submetering, and IoT platforms. The results of the test will show that the data can be collected, consolidated, and made available to the upstream processes such as optimisation, data analytics, and Contracting Platforms. The test considers the whole LEC, including smart thermostats, PV arrays, controllable heating systems, and smart meters, which will be monitored and/or managed. The Reengen gateways will be responsible for collecting and storing the data on the Reengen IoT Platform, which can be used for optimisation, data analytics, and identity management. To extract data from the platform, necessary connections such as Restful API should be established. The Reengen IoT Platform will receive the request for baseline and availability requests and then triggers and reports forecasts, and computes the baseline to the contracting platform.
KPIs	Energy KPIs: • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC
Prerequisites	The IoT gateways need to be installed and defined (Register mapping) on our platform. For data extraction from the platform, necessary connections (Restful API) should be done.
Assumptions	Not applicable.
Measured and calculated variables	• Electricity production, by source (PV) • Electricity consumption, by consumer type • Electricity import/export • Heat production, by producer type (heat pump/ immersion heater) • Heat storage temperatures and flow • Heat consumption by end-usage and flexibility
Benchmark	• Data will be available at the resolution required for forecasting and community optimisation.
FUNCTIONAL PERFORMANCE TEST #2 TROYA (GÖKÇEADA ISLAND)	
Test name	**Functional performance test for edge computation**
Developments to test	Edge-computation capable gateways and optimizers will be transmitting and extracting data from the Reengen IoT platform. It will gather high-quality data, incorporating forecasting algorithms, optimisation and control strategies for LECs and associated services (e.g., peak load control by heat-pumps/buildings) by LECs. Capabilities of Reengen IoT gateways can be summarised as: • Receiving requests and boundary conditions for optimisation • Conducting energy resource forecasts • Calculate and determining setpoints • Pushing setpoints to energy resources • Verifying device shift to setpoint

Objective	Demonstrate that relevant computation for forecasting and optimisation are matching or close to actual data. Successful data integration into the IoT platform.
Scope	The whole LEC is considered. Assets to monitored and/or managed: ● PV system ● Heat pump ● Battery storage ● Smart metre
Description	The Functional performance test for edge computation involves the use of gateways and optimizers that are capable of edge computation. These gateways and optimizers will be responsible for transmitting and extracting data from the Reengen IoT platform. The test aims to gather high-quality data by incorporating forecasting algorithms, optimisation, and control strategies for LECs and their associated services. The test covers the entire LEC, ensuring that all components of the LEC are considered.
KPIs	<u>Energy Performance Indicators:</u> ● **KPI_EN_1:** Final energy consumption at building/household level ● **KPI_EN_2:** Final energy consumption in the LEC ● **KPI_EN_4:** On-site renewable energy consumption in the LEC <u>Hardware/ICT Key Indicators:</u> ● **KPI_IoT_1**: Algorithm and forecast execution performance ● **KPI_Edge_1**: Transferability of optimisation algorithm
Prerequisites	The IoT gateways need to be installed and defined (Register mapping) on our platform. Forecasting and optimisation algorithms that will run on IoT gateways should be installed.
Assumptions	Not applicable.
Measured and calculated variables	The ones considered in the KPI definition.
Benchmark	Not applicable.
FUNCTIONAL PERFORMANCE TEST #3 TROYA (GÖKÇEADA ISLAND)	
Test name	**Functional performance test for sub-meter device**
Technical development to test	The sub-metering device developed in Task 5.2 by SmartHelio.
Objective	Evaluate the functional performance of the sub-metering device.
Scope	The production device will be deployed in one PV-module of TROYA cooperative PV installation.
Description	An LTE connection will also be established to the SmartHelio cloud.

	Forecasting performance will be evaluated in accordance with the definitions in the KPI's listed in the next section. Forecasting will be conducted for day ahead and hour ahead time periods at a resolution of 15 minutes (hour ahead) and 60 minutes (day ahead). Data will be collected to enable the execution of the forecasts.
KPIs	All forecasting KPI's, applied to the specific case of PV forecasting.
Prerequisites	Data connection must be established with the sub-metering device. Data collection must be established with a cloud weather forecasting service.
Assumptions	Weather forecasts will be obtained from a cloud-based forecasting service: no weather forecasting will be conducted on-device.
Measured and calculated variables	Measured values: power, current, voltage, temperature. Calculated values: forecast power for the array, based on module measurements obtained from the edge device.
Benchmark	Forecasts will be compared with actual measured values of power.
FUNCTIONAL PERFORMANCE TEST #4 TROYA (GÖKÇEADA ISLAND)	
Test name	**Functional performance test for the Prosume cloud**
Technical development to test	Prosume cloud is used for settlement and smart contracts. It integrates the DLT-based community manager platform, DLT-based prosumer account platform, DSO contracting platform and the Mobile-app for interaction with the user.
Objective	Certificate the veracity of identities, entities, data and transactions.
Scope	Local Energy Communities members and interactions.
Description	The service will evaluate several factors to formalise data or services bid/ask.
KPIs	Prosume cloud KPIs: • **KPI_Pro_1**: Quantity of identities (users) of an Energy Community in a Mobile Pro • **KPI_Pro_2**: Quantity of transactions between users members of the same community • **KPI_Pro_3**: Ratio of successful transactions
Prerequisites	• Anonymous data and transaction tracking
Assumptions	None.
Measured and calculated variables	The service will define data ownership, origin and destination, and the incentive sharing model (equally, linked to investment, linked to self-consumption...)
Benchmark	The base scenario will require auditing previous user and data interactions of energy communities currently deployed.

Forecasting in Troya Cooperative island LEC overview

Table 26 described the verification of forecasting in Gökçeada island.

Table 26 - Forecasting evaluation test in Troya cooperative (Gökçeada island).

FORECASTING EVALUATION IN TROYA (GOKÇEADA ISLAND)	
Test name	**Forecasting algorithms verification and evaluation**
Developments to test	• PV production forecasting • Consumers' load curves forecasting • Building forecasting
Objective	Evaluate the accuracy of the forecasting algorithms.
Description	The forecasting algorithms are validated by comparing the results computed by the algorithm with a baseline method, against actual data, or against those made by a human expert. Therefore, it is necessary to define if the comparison is quantitative or qualitative and the threshold.
KPIs	Forecasting accuracy KPIs: • **KPI_FO_1**: Forecasting error
Data requirements	Period of time with historized data: one year Granularity of the data: hourly
Required measured variables	PV forecasting: PV production and meteorological variables. Consumer's load curves forecasting: electric consumption data. Heat forecasting: thermal consumption data.
Benchmark	The real measurements of the PV production, heat consumption and load will be compared to the forecasted values by the algorithms.

GENTE validation in Troya Cooperative island LEC overview

Test case #1 TROYA Cooperative (Gökçeada island): CO_2 emissions reduction

The test case for CO_2 emissions reduction (UC2) in the Çanakkale island is described in Table 27.

Table 27 - CO_2 emissions reduction test case in Troya cooperative (Çanakkale island).

TEST CASE #1 TROYA (GOKÇEADA ISLAND)	
Test name	**LEC optimisation for CO_2 emissions reduction**
Developments to test	The GENTE optimizer that aims to reduce the CO_2 emissions of the LEC. This tool, developed by HSLU in WP5, makes decisions on flexible assets while taking into account the electricity prices, weather forecast and self-consumption. The

	tool is deployed on-site, and Reengen's IoT platform enables integrating distributed assets and data sources.
Objective	Demonstration of CO_2 emissions reduction in the community through the optimisation algorithms.
Scope	The TROYA (Çanakkale island) energy assets monitored and controlled: ● Smart thermostats ● PV modules ● Heat pumps ● Smart metres
Description	The Functional performance test for LEC optimisation aims to reduce CO_2 emissions by deploying green LECs as an alternative to fossil-fuel-based power generation. The test is designed to bring intelligence to the grid edge, enabling decentralised control of green LECs using data analytics technology. The primary goal of this test is to achieve a reduction in CO_2 emissions, and this will be accomplished through the deployment of green LECs. These green LECs will be controlled using data analytics technology, which will enable intelligent and decentralised control at the grid edge. By deploying green LECs and reducing the reliance on fossil-fuel-based power generation, this test aims to achieve a significant reduction in CO_2 emissions.
KPIs	Energy KPIs: ● **KPI_EN_1**: Final energy consumption at building/household level ● **KPI_EN_2**: Final energy consumption in the LEC ● **KPI_EN_3**: On-site renewable energy production in the LEC ● **KPI_EN_4**: On-site renewable energy consumption in the LEC ● **KPI_EN_5**: LEC self-consumption quota ● **KPI_EN_7**: Grid electricity usage reduction Environmental KPIs: ● **KPI_ENV_1**: CO_2 emissions during operation ● **KPI_ENV_2**: Reduction of CO_2 emissions
Prerequisites	The functional performance tests should have been accomplished successfully.
Assumptions	Any considered assumption for the test case.
Measured and calculated variables	In accordance with the KPI definition.
Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period.

Test case #2 TROYA Cooperative (Gökçeada island): Community autarky increase

Table 28 describes the test case related to the community autarky increase (UC3c) in Çanakkale island.

Table 28 - Community autarky increase test case in Troya cooperative (Çanakkale island).

TEST CASE #2 TROYA (GOKÇEADA ISLAND)	
Test name	**Community autarky increase**
Technical development to test	The overall system is aimed to serve increasing autarky of the LEC. With the integration of IoT gateways to the sub-metering devices, necessary analysis, and device management for flexible assets (heat pumps) can be set and established by considering solar production.
Objective	Demonstration of community autarky increase in the community through the optimisation algorithms.
Scope	The TROYA (Çanakkale island) energy assets monitored and controlled: ● Smart thermostats ● PV modules ● Heat pumps ● Smart metres
Description	The IoT gateways will collect consumption and forecast data from sub-metering devices and SmartHelio clouds, and transmit them into the Reengen IoT platform, where other project partners such as HSLU can gather those data and use them in device management and optimisation purposes. In this way, Reengen platform and IoT gateways will act as a bridge between devices and platforms for better management and autarky. The objective is to increase the community autarky through the self-consumption maximisation coming from renewable sources.
KPIs	Energy KPIs: ● **KPI_EN_1**: Final energy consumption at building/household level ● **KPI_EN_2**: Final energy consumption in the LEC ● **KPI_EN_3**: On-site renewable energy production in the LEC ● **KPI_EN_4**: On-site renewable energy consumption in the LEC ● **KPI_EN_5**: LEC self-consumption quota ● **KPI_EN_6**: Reschedulable renewable energy use ● **KPI_EN_7**: Grid electricity usage reduction
Prerequisites	The functional performance tests should have been accomplished successfully.
Assumptions	Not applicable.
Measured and calculated variables	As defined in the KPI's listed above.
Benchmark	A baseline scenario will be generated with historic data based on the IPMVP procedure, considering the required adjustments for the external conditions (i.e. weather conditions). The savings will be calculated by comparing the adjusted baseline with the GENTE reporting period.

Test case #3 TROYA Cooperative (Gökçeada island): Grid flexibility availability evaluation

Table 29 reflects the test description for an evaluation of the grid flexibility provision.

Table 29 - Grid flexibility availability evaluation test case in Troya cooperative.

TEST CASE #2 TROYA (GOKÇEADA ISLAND)	
Test name	**Grid flexibility availability evaluation**
Developments to test	The GENTE optimizer that aims to provide flexibility of the LEC. This tool, developed by HSLU in WP5, makes decisions on flexible assets (flexible loads such as EV charging, or electric/heat storage) while taking into account the electricity prices, weather forecast and self-consumption. The tool is deployed on-site, and Reengen's IoT platform enables integrating distributed assets and data sources.
Objective	Evaluation of the possible flexibility provision that the LEC is able to comply for.
Scope	The whole LEC is considered. Assets to monitored and/or managed: • PV system • Hydro power • Heat pump • Heat storage • EV station • Battery storage • Smart meter
Description	A simulation of peak load management and self consumption optimisation will be used to demonstrate the feasibility of providing grid services in this test site.
KPIs	<u>Energy KPIs:</u> • **KPI_EN_1**: Final energy consumption at building/household level • **KPI_EN_2**: Final energy consumption in the LEC • **KPI_EN_3**: On-site renewable energy production in the LEC • **KPI_EN_4**: On-site renewable energy consumption in the LEC • **KPI_EN_5**: LEC self-consumption quota • **KPI_EN_6**: Reschedulable renewable energy use • **KPI_EN_7**: Grid electricity usage reduction
Prerequisites	Set points can be realised without disruption of user comfort.
Assumptions	Any considered assumption for the test case.
Measured and calculated variables	• Electricity production, by source (PV) • Electricity consumption, by consumer type • Electricity import/export • Heat production, by producer type (heat pump/ immersion heater) • Heat storage temperatures and flow

	• Heat consumption by end-usage and flexibility
Benchmark	A benchmark is calculated as part of the process.

User-engagement assessment through Mobile-App interactions

An assessment of the user-engagement level through Prosume's Mobile-App will be performed according to the test description provided in Table 30.

Table 30 - User-engagement evaluation in Troya cooperative.

Social assessment	
Test name	**User-engagement (through mobile app interaction)**
Responsible partners	Prosume
Technical development to test	• GENTE's One-Stop-Shop as a Mobile-First app with powerful metrics, personal energy management and best practices awarding system developed in Task 4.4. • DLT-based community manager platform • DSO contracting platform • DLT-based prosumer account platform
Objective	Measuring the number of interactions between entities (energy assets) and identities (users).
Scope	User of the Local Energy Community.
Test-site	The mobile app should be used by any energy community that requires this user engagement layer, mainly the ones that are being developed or are open to integrate new members.
Description	Establish rankings between most efficient communities (federation of communities approach) and most efficient users of each community. Facilitate the engagement of new members sending specific invitations to users that asks to be part of a specific community
KPIs	<u>End user engagement related KPIs:</u> • **KPI_SOC_1**: Quantity of identities (users) • **KPI_SOC_2**: Interactions of each user with the Mobile app • **KPI_SOC_3**: Ratio of active and non-active number of users <u>Functional performance KPIs:</u> • **KPI_Pro_2**: Quantity of transactions between users members of the same community • **KPI_Pro_3**: Ratio of successful transactions

Prerequisites	• Metering data from all energy assets involved in a community • Acceptance of Terms and Conditions, already defined, and acceptance of KYC policy to formalise transactions between users
Assumptions	-
Measured and calculated variables	Energy data coming from field devices such as PV production, energy consumption, energy used by batteries and heat pumps…
Benchmark	The baseline scenario will be defined based on energy consumption historical data of each demo-site or using real data from the communities already established that are using some kind of EMS.

GENTE validation in federations of communities

GENTE aims to promote LEC federation by developing solutions for the energy management of federations of LEC. In order to validate the use case related to community federation, a test case is proposed in Table 31.

Table 31 - LEC optimisation for community autarky increase test case in Am Aawasser.

COMMUNITY FEDERATION TEST CASE	
Test name	**Community federation**
Developments to test	The GENTE solution for community federation, based on optimisation algorithms for the energy management at federation levels.
Objective	Demonstration at virtual level of the energy communities federation optimisation. The LEC optimisation algorithms are extended to consider not just the energy assets of one LEC, but of a federation of communities.
Scope	Different federations will be considered among the GENTE pilot LECs at virtual level, using real operation data collected from Am Aawasser, Swedish sites (HSB living lab and Alingsås pilot) and Troya energy communities.
Description	Federation level, governance methods allow management of the community, create the ability to offer resources as a service, monitor and control performance, or manage flexibility requests and offers (based on, e.g., demand response/heat-pump control, building control, flexibility services to the DSO grids, etc.). GENTE will formulate a decentralised monitoring and control system concept for LECs and their integration in larger scales, allowing the community manager to monitor a portfolio of energy communities, for example by allowing them to **federate community assets**, **calculate the available flexibility and the financial status to interact with community members and external actors** (i.e. the federation manager). The federation manager would have the ability to monitor the activity of the energy communities, interface with external markets, and with communities' assets. Algorithms will be proposed and tested in at least one of the three demonstration sites to identify the bottlenecks for the wider roll-out. Implementation will be in a hybrid simulation - real world setup, allowing federation to be investigated and demonstrated where practical constraints (e.g. regulations, grid constraints, controllability of resources) prevent actual full implementation. Privacy and data security will be ensured through the governance models enabled by DLT. The LEC federation will be tested in 3 different virtual scenarios: • Scenario 1: **Flexibility federation to minimise local network congestion**. A hypothetical case will be created where two adjacent

	energy communities are optimised, based on data collected from the Am Aawasser, Swedish or Troya sites. The ability for local resource optimisation to limit adverse impacts on the local electricity network will be assessed, considering peak load management and self consumption optimisation. A simple assumption about the local network will be made (HSLU). ● Scenario 2: **Federation for a VPP**. A reference aggregator setpoint will be provided to the Prosume contracting platform. Flexibility requests will be made in simulation to assess the ability of federated LEC's to respond to the aggregator requests. ● Scenario 3: **Contractual federation**. The commercial and contractual value associated with community federation through the Prosume platform will be assessed (Prosume).
KPIs	Energy KPIs Economical KPIs
Prerequisites	Sufficient and adequate data will be available to allow simulation of the test case.
Assumptions	These tests will be performed at virtual level by simulating the federation of LECs. Simple assumptions about local networks will be performed.
Measured and calculated variables	All the energy and economic flows calculated during the simulations will be saved and used for the KPIs calculation.
Benchmark	The baseline scenarios will be greeted virtually through simulation.

Key Performance Indicators

The contractual KPIs stated at GENTE proposal are presented in Table 32.

Table 32 - GENTE use cases definition.

#	KPI	Value	Measured by
1	New services to the DSO	2 new	Demonstrated in WP9
2	Community CO_2 emissions reduction	Up to 30%	Calculated from measurements in WP9
3	User interaction with platform through living lab	200 users 2 communities	Measured in WP9 and shown in WP2
4	Improved community energy efficiency	Up to 30%	Demonstration in living labs/simulation

In order to support the monitoring and contribute to the validation of the contractual KPIs, a set of internal KPIs have been defined. These KPIs enable a multi-domain assessment for the validation process. This chapter describes in detail the various internal project monitoring KPIs that will be used for the validation and their calculation methodology.

Energy Key Performance Indicators

A set of KPIs related to energy area are defined to provide quantitative measures of the energy performance of the community, the amount of renewable energy integration and self-consumed, grid congestion and other relevant metrics for the assessment of the GENTE solutions for the energy management. These KPIs are presented in Table 33.

Application of the KPI depends on values being available in a given test case or community. Where values are not available (e.g. no thermal metering), the calculation will be adapted.

Table 33 - Energy Key Performance Indicator list for assessment.

KPI ID	KPI Name
KPI_EN_1	Final energy consumption at building/household level
KPI_EN_2	Final energy consumption in the LEC
KPI_EN_3	On-site renewable energy production in the LEC
KPI_EN_4	On-site renewable energy consumption in the LEC
KPI_EN_5	LEC self-consumption quota
KPI_EN_6	Reschedulable renewable energy use

KPI_EN_7	Grid electricity usage reduction
KPI_EN_8	Energy savings triggered by the project

Table 34 contains a detailed description of these KPIs:

Table 34 - Energy Key Performance Indicator description, calculation methodology and relevant characteristics.

KPI_EN_1	
KPI name	**Final energy consumption at building/household level**
Definition	Total amount of energy that is consumed at each building/household to cover the energy demand independently of their origin, either local or remote. The total amount of energy refers to the sum of the different energy vectors, that, for the considered LECs, are electric and thermal.
Type	Quantitative
Calculation / methodology	$E_{f,i} = E_{el,i} + E_{th,il}$ $E_{f,i} =$ Final energy consumption at household *i* [kWh] $E_{el,i} =$ Total electric consumption at household *i* [kWh] $E_{th,i} =$ Total thermal consumption at household *i* [kWh] Both the monthly final energy consumption at each household [MWh/month] for all the validation months, and the hourly distribution of final energy consumption at household level [kWh] will be used for the assessment.
Data source	Measured or estimated through simulations.
Required data points	Measurement of electric energy consumption at household level. In those cases in which a thermal energy source is available (i.e. connection to a district heating), total thermal energy consumption measurement is also required.
Unit	[kWh] or [MWh/month]
Relation to target	Energy efficiency improvement at building level, CO_2 emissions reduction
KPI_EN_2	
KPI name	**Final energy consumption in the LEC**
Definition	Total amount of energy that is consumed within the community to cover the energy demand of all the households in the community, independently of the energy origin, either local or remote. The total amount of energy at each household refers to the sum of the different energy vectors (in this case, electric and thermal).
Type	Quantitative

Calculation / methodology	$E_{f,LEC} = \sum_{i=1}^{N} E_{f,i} = \sum_{i=1}^{N} (E_{el,i} + E_{th,i})$ $E_{f,LEC}$ = Final energy consumption in the LEC [kWh] $E_{f,i}$ = Final energy consumption at each household *i* of the LEC [kWh] $E_{el,i}$ = Total electric consumption at household *i* [kWh] $E_{th,i}$ = Total thermal consumption at household *i* [kWh] N = Total number of household that are part of the community Both the monthly final energy consumption at each household [MWh/month] and the hourly distribution of final energy consumption at household level [kWh] will be used for the assessment.
Data source	Measured or estimated through simulations.
Required data points	Total energy consumption at household level (electric+"thermal"), or total LEC consumption if it is directly available.
Unit	[MWh/month] or [kWh]
Relation to target	Energy efficiency improvement at LEC level, CO_2 emissions reduction, Grid flexibility provision
KPI_EN_3	
KPI name	**On-site renewable energy production in the LEC**
Definition	Total renewable energy production in the LEC, before being self-consumed or injected in the grid. This indicator refers to the on-site production of renewable energy for the different energy vectors utilised on-site (i.e. electric, thermal).
Type	Quantitative
Calculation / methodology	E_{RES} = Total renewable energy production in the LEC [kWh] Both the monthly total on-site renewable production in the LEC [MWh/month] and the hourly distribution of on-site renewable energy production [kWh] will be used for the assessment.
Data source	Measured
Required data points	Total on-site renewable production measurement (i.e. PV production on-site). Inverter-level data is required.
Unit	[MWh/month] or [kWh]
Relation to target	Energy efficiency improvement at LEC level, CO_2 emissions reduction, Grid flexibility provision
KPI_EN_4	
KPI name	**On-site renewable energy consumption in the LEC**

Definition	Total amount of renewable energy that is produced on-site and consumed within the LEC (so, it is not injected in the grid). This indicator refers to the on-site production of renewable energy for the different energy vectors utilised on-site (i.e. electric, thermal).
Type	Quantitative
Calculation / methodology	$E_{cons,RES}$ = Total renewable energy consumption in the community [kWh] Both the monthly total on-site renewable consumption in the LEC [MWh/month] and the hourly distribution of on-site renewable energy consumption [kWh] will be used for the assessment. Depending on the available measurements. If the household energy consumption, the total on-site renewable production and the energy injected to the grid are measured: $E_{cons,RES} = E_{RES} - E_{RES,inj}$ $E_{cons,RES}$ = Total renewable energy consumption in the community [kWh] E_{RES} = Total renewable energy production in the LEC [kWh] $E_{RES,inj}$ = Total on-site produced renewable energy that is injected in the grid [kWh]
Data source	Calculated from measurements or estimated through simulations, depending on the available measurements in each pilot and the RES production units installation scheme.
Required data points	Measurements of: • Total renewable production on-site • Injected energy from the total on-site renewable energy production Insufficient metering coverage may limit the ability to fully compute self consumption.
Unit	[MWh/month] or [kWh]
Relation to target	Community self-consumption, Grid flexibility provision services
KPI_EN_5	
KPI name	**LEC self-consumption quota**
Definition	Percentage of the on-site renewable production that is consumed on-site in the LEC (and not injected to the grid), that is, it represents the percentage of renewable production which is used for self-supply. It can be calculated for each energy vector, or for all the energy vectors jointly.
Type	Quantitative
Calculation / methodology	$SC_{LEC} = \frac{E_{cons,\,RES}}{E_{RES}} \cdot 100$ [%] SC_{LEC} = Self-consumption quota in the LEC [%] $E_{cons,\,RES}$ = Total on-site renewable energy consumption in the LEC [kWh]

	E_{RES} = Total on-site renewable energy production in the LEC [kWh]
Data source	Calculated from measurements or estimated through simulations
Required data points	Required data: • Total on-site renewable energy consumption (calculated from measurements) • Measurement of total energy consumption in the LEC
Unit	%
Relation to target	Community self-consumption, Grid flexibility provision services
KPI_EN_6	
KPI name	**Reschedulable renewable energy use**
Definition	Ratio between renewable electricity available for use in grid balancing and total electricity generated. The available renewable electricity for grid balancing is the energy that is injected in the grid.
Type	Quantitative
Calculation / methodology	$RE = \frac{E_{RES,inj}}{E_{RES}}$ when $E_{RES,inj} > 0$ RE = Reschedulable renewable energy use [kWh] $E_{RES,inj}$ = Total on-site renewable energy that is injected into the grid [kWh] (it will be considered just the cases in which $E_{RES,inj} > 0$) E_{RES} = Total on-site renewable energy production in the LEC [kWh]
Data source	Calculated from measurements.
Required data points	• Measurement of the total on-site renewable production • Measurement of the on-site renewable energy that is injected to the grid
Unit	kWh
Relation to target	Grid flexibility provision services
KPI_EN_7	
KPI name	**Grid electricity usage reduction**
Definition	The reduction in the energy purchased from the grid due to the installation of RES or the improvement of self-consumption in the LEC.
Type	Quantitative
Calculation / methodology	$RG = \frac{(E_{grid,0} - E_{grid,GENTE})}{E_{grid,0}} \cdot 100$ RG = Total reduction of electricity purchased to the grid in the LEC [%]

	$E_{grid,0}$ = Total energy purchased to the grid before GENTE [kWh] $E_{grid,GENTE}$ = New energy purchased to the grid after GENTE solutions integration [kWh]
Data source	• Measurement of the original energy purchased from the grid. • Measurement of the new energy purchased from the grid after the application of the GENTE solutions.
Unit	%
Relation to target	Grid flexibility provision
KPI_EN_8	
KPI name	**Energy savings triggered by the project at household/LEC**
Definition	The real reduction in energy consumed by a household or by the total members of the community.
Type	Quantitative
Calculation / methodology	$ES = \frac{(E_{cons,0} - E_{cons,opt})}{E_{cons,0}} \cdot 100$ ES = Total energy savings at household or LEC [%] $E_{cons,0}$ = Total original consumption in the household/LEC [kWh] $E_{cons,opt}$ = New energy consumption in the household/LEC (with the optimisation algorithms GENTE) [kWh]
Data source	• Measurement of the original consumption in the household/LEC. • Measurement of the new consumption with the optimisation algorithms (if the optimisation developments are integrated on-site) or estimated through simulation (for virtual validation tests).
Unit	%
Relation to target	Energy efficiency of the building / LEC

Environmental Key Performance Indicators

As one of the main targets of the GENTE project is the reduction of CO_2 emissions, it is important to define environmental KPIs that help to assess and validate this objective. These KPIs are listed in Table 35.

Table 35 - Environmental Key Performance Indicator list for assessment.

KPI ID	KPI Name
KPI_ENV_1	CO_2 emissions during operation

KPI_ENV_2	Reduction of CO_2 emissions

Table 36 contains a detailed description of these KPIs:

Table 36 - Environmental Key Performance Indicator description, calculation methodology and relevant characteristics.

KPI_ENV_1	
KPI name	**CO_2 emissions during operation**
Definition	The total carbon dioxide (CO_2) emissions during the operation based on the on-site produced and grid-imported energy vectors that are consumed and its corresponding CO_2 emissions factors.
Type	Quantitative
Calculation / methodology	$Eq_{CO_2} = \sum_{j}^{j=M} CF_j \cdot E_{cons,j}$ Eq_{CO_2} = Total equivalent CO_2 emissions during a month [$tCO_2eq/month$] CF_j = Conversion factor for each energy source *j* (i.e. PV production, fuel, grid purchased energy) [tCO_2eq/MWh] $E_{cons,j}$ = Total energy consumption in the LEC from each energy source *j* (i.e. PV production, fuel, grid purchased energy) [MWh/month]
Data source	Calculated from measurements
Required data points	• Total energy consumption measurement, differentiating between the energy consumed that is produced locally by renewable sources, the energy which is imported and consumed from the grid and other possible energy sources • CO_2 conversion factors for each fuel/source that is used. The most recent values reported on the Covenant of Mayors (CoM) will be used for the emission factors of different sources and fuels[1]. • CO_2 conversion factors for each national electricity grid mix. The most recent values reported for Sweden[2], Switzerland[3] and Turkey[4] will be used for the emission factors corresponding to the grid energy mix of each country. [1] Joint Research Centre Data Catalogue - CoM Default Emission Factors - European Commission (europa.eu) [2] Joint Research Centre Data Catalogue - GHG Emission Factors for Electricity Consumption - European Commission (europa.eu) [3]Accueil (horocarbon.ch) [4]CT2021Turkey.pdf (climate-transparency.org) Note: in those cases in which a local service is used for the CO_2 electricity mapping (such as HSB living lab), those values will be also used for the CO_2 emissions calculation.
Unit	$tCO_2eq/month$ (equivalent CO_2 tons / month)

Relation to target	CO_2 emissions reduction
KPI_ENV_2	
KPI name	**Reduction of CO_2 emissions**
Definition	Reduction in the equivalent CO_2 emissions saved due to the change in the energy source or due to implementation of energy efficiency solutions (such as management systems that improve the overall efficiency).
Type	Quantitative
Calculation / methodology	$R_{eq,CO_2} = \frac{Eq_{CO_2}^{base} - Eq_{CO_2}^{opt}}{Eq_{CO_2}^{base}} \cdot 100$ R_{eq,CO_2} = Total reduction in the equivalent CO_2 emissions [%] $Eq_{CO_2}^{base}$ = Total equivalent CO_2 emissions for the baseline scenario during a month [tCO_2eq/month] $Eq_{CO_2}^{opt}$ = Total equivalent CO_2 emissions for the new scenario during a month (with a different energy source mix or with a change in the total energy consumption) [tCO_2eq/month]
Data source	Real measured data (energy consumption) or estimated/simulated
Required data points	
Unit	Equivalent CO_2 kg
Relation to target	Community CO_2 emissions reduction

Social Key Performance Indicators

Social KPIs are defined to assess the users' engagement within the community and the benefits they perceive. In order to promote the social involvement of the LEC users, GENTE gathers user-engagement activities, the establishment of a co-creation process that helps integrating, prioritising and putting the focus on users' needs during the development of the GENTE technical solutions. Moreover, the mobile app developed within GENTE also has an important role regarding the user-engagement, as it is a key enabler of making the users feel part of the community and interact with it.

Therefore, the social KPIs are defined to cover all these aspects: KPIs to evaluate the user-engagement through the Mobile app, and KPIs related to the user-engagement and co-creation process impact on it and KPIs related to perceived benefits. These KPIs are listed in Table 37.

Table 37 - Social Key Performance Indicator list for assessment.

KPI ID	KPI Name
Social KPIs related to the Mobile App	
KPI_SOC_1	Quantity of identity (users)

KPI_SOC_2	Interaction of each user with the Mobile app
KPI_SOC_3	Ratio of active and non-active number of users
Social KPIs related to the co-design process	
KPI_SOC_4	Overall satisfaction with co-design process
KPI_SOC_5	Engagement of potential users (active and passive)
KPI_SOC_6	Co-design participant diversity
KPI_SOC_7	Stakeholders quantification

A detailed description of the social KPIs is presented in Table 38.

Table 38 - Social Key Performance Indicator description, calculation methodology and relevant characteristics.

Social KPIs related to the Mobile App	
KPI_SOC_1	
KPI name	**Quantity of identity (users) of a Energy Community in a Mobile App**
Definition	Number of identity (users) that are part of an Energy Community and are registered in the Mobile App.
Type	Quantitative
Calculation / methodology	User database with anonymous IDs
Data source	Monitored value in the Mobile App
Required data points	User's ID in a Energy Community
Unit	-
Relation to target	End-user engagement
KPI_SOC_2	
KPI name	**Interaction of each user with the Mobile app**
Definition	Number of interactions for each user of the Mobile App. It is considered as an **interaction** one of the following actions: • make a request to use an energy asset owned by another member of the community • send an invitation to a new user • settle a contract (incentive sharing, invoice payments...).
Type	Quantitative
Calculation / methodology	Mobile app logs

Data source	Monitored value in the Mobile App
Required data points	Register with all the interactions of users
Unit	-
Relation to target	End-user engagement
KPI_SOC_3	
KPI name	**Ratio of active and non-active number of users**
Definition	Ratio between the number of members that are active within the community and the members that are non-active. Being an active user requires interacting at least **once a week** with the community through the Mobile app.
Type	Quantitative
Calculation / methodology	Mobile app logs
Data source	Monitored value in the Mobile App
Required data points	Register with all the logs in the mobile apps
Unit	-
Relation to target	End-user engagement
Social KPIs related to co-design process	
KPI_SOC_4	
KPI name	**Overall satisfaction with co-design process**
Definition	Indicator of the overall degree of satisfaction of the participants in the co-design process regarding its participation in it. The satisfaction evaluation will be conducted based on sub-dimensions, e.g.: • Do the participants find the process comprehensible? • Do the participants feel their suggestions were heard? • Do the participants feel they could make a difference? • Do the participants think satisfactory explanations were given when their suggestions were refused?
Type	Qualitative
Calculation / methodology	Assessment through collection of user feedback through a survey.
Data source	Survey
Required data points	
Unit	Standardised Likert scales (e.g. 5-point agreement/disagreement)

Relation to target	End-user engagement
KPI_SOC_5	
KPI name	**Engagement of potential users (active and passive)**
Definition	Proportion of users within a potential community (e.g. residential development) who comply with at least one of this points: - register (or do not refuse) to be informed about ongoing development of an energy community (passive users) - who participate in the co-design workshops and the survey (active users)
Type	Quantitative
Calculation / methodology	Number and proportion of adult tenants who opt in to (or do not opt out of) receiving regular updates on the co-design process. e(i) = a(opt-in) / a(total)*100% e(i): proportion of adults who choose to receive information on co-design process a(opt-in): number of adults who choose to receive information on co-design process (emails) a(total): number of total adults in test-site Proportion of households within the test site who participate in the workshop e(w) = hh(workshop) / hh(total)*100% e(w): proportion of households engaged in workshops hh(workshop): number of households participating in workshop(s) hh(total): number of total households in test-site Proportion of households within the test site who participate in the survey e(s) = hh(survey) / hh(total)*100% e(s): proportion of households engaged in survey hh(survey): number of households participating in survey hh(total): number of total households in test-site
Data source	Mailing list, residents list, workshop attendance lists, survey participation data, data from site manager
Required data points	

Unit	%
Relation to target	End-user engagement
KPI_SOC_6	
KPI name	**Co-design participant diversity**
Definition	Diversity of participants involved in co-design process Reference is the diversity of all potential participants, e.g. all tenants of the test-site. Variables: age group, gender, educational attainment, nationality, household type. For each variable define categories: e.g. age: 18-26, 27-34, 35-50, 51-64, 65+ ; gender: male/female/diverse, education: none, vocational/secondary, tertiary; nationality: national of site-country/non-national; household type: single, 2 adults no children, 1 adult 1+ children, 2 adults 1+ children, 3+ adults with/without children) Create a distribution table for each variable.
Type	Qualitative/quantitative
Calculation / methodology	chi-square estimate of equal distribution for each variable qualitative assessment of under/over represented categories based on tables
Data source	Survey of participants, data on tenants from site manager
Required data points	*See variables above; this is only possible for variables where the site-manager can provide us a distribution table.*
Unit	%
Relation to target	End-user engagement
KPI_SOC_7	
KPI name	**Stakeholder quantification**
Definition	Number of stakeholders beyond potential end users involved in the co-design process (site manager, local dso, local engineering firms etc.)
Type	Quantitative

Calculation / methodology	$N_s = \sum_{i=m}^{n} x_i = i_m + i_{m+1} + i_{m+2} + ... + i_n$ N_s = Number of stakeholders involved in co-design process i is the sum index m is the lower limit n is the upper limit x represents a stakeholder
Data source	Attendance lists etc..
Required data points	Number and type of engaged stakeholders
Unit	-
Relation to target	Stakeholder diversity of co-design process

Hardware/ICT Key Performance Indicators

A set of KPIs to demonstrate the functional performance of the new hardware are included, which includes the operating of the system and the communication with the rest of the system architecture components. These KPIs are centred in the main new hardware: IoT gateways, edge intelligence, PV sub-metering device and Prosume cloud. They are listed in Table 39.

Table 39 - Hardware/ICT Key Performance Indicator list for assessment.

IoT gateway	
KPI ID	KPI Name
KPI_IoT_1	Algorithm and forecast execution performance
Edge Intelligence	
KPI ID	KPI Name
KPI_Edge_1	Transferability of optimisation algorithm
Prosume cloud	
KPI ID	KPI Name
KPI_Pro_1	Quantity of identities (users) of an Energy Community in a Mobile App
KPI_Pro_2	Quantity of transactions between users members of the same community
KPI_Pro_3	Ratio of successful transactions

BEMS	
KPI ID	**KPI Name**
KPI_BEMS_1	Delay/latency in data collection

The hardware KPIs related to the IoT gateways are described in Table 40.

Table 40 - IoT gateway Key Performance Indicator description, calculation methodology and relevant characteristics.

KPIs related to the IoT Gateway	
KPI_IoT_1	
KPI name	**Algorithm and forecast execution performance**
Definition	The IoT Gateway consists of Rasperry pi 3 as mainboard, ARM-Contex-A53 as 4 cores processor. The gateway is capable of transmitting data at 1.2 GHz and also has 1 GB memory. With these hardware capabilities, IoT Gateways can handle necessary forecasts and algorithms with the highest performance.
Type	Quantitative
Calculation / methodology	The execution time for algorithms will be measured by observing cycle times and duration of execution.
Data source	-
Required data points	-
Unit	Seconds
Relation to target	Edge Intelligence

The KPIs related to the sub-metering device functional performance are explained in Table 41.

Table 41 - Edge Intelligence Key Performance Indicator description, calculation methodology and relevant characteristics.

KPIs related to the edge intelligence	
KPI_Edge_1	
KPI name	**Energy resource compatibility**
Definition	The optimisation algorithm should be compatible with at least: PV, community storage, electrical heat pumps.
Type	Qualitative
Calculation / methodology	Functional appraisal
Data source	Source code of optimisation algorithm

Required data points	Source code
Unit	Not applicable
Relation to target	Functional performance test of edge intelligence

The KPIs related to the sub-metering device functional performance are explained in Table 42.

The KPIs related to the Prosume cloud are collected in Table 42.

Table 41 - Prosume cloud Key Performance Indicator description, calculation methodology and relevant characteristics.

Prosume cloud functional performance KPIs	
KPI_Pro_1	
KPI name	**Quantity of identities (users) of an Energy Community in a Mobile Pro**
Same as	KPI_SOC_1
KPI_Pro_2	
KPI name	**Quantity of transactions between users members of the same community**
Definition	Number of transactions that are conducted between the user members of the same community **monthly**. Both credit transactions between users or user to service provider are considered.
Type	Quantitative
Calculation / methodology	
Data source	Registered in the Mobile App
Required data points	Which data measurement or values are required.
Unit	-
Relation to target	Functional performance / auditability of the Mobile App
KPI_Pro_3	
KPI name	**Ratio of successful transactions**
Definition	Number of transactions that are conducted successfully. A transaction is considered successful when the settlement is completed: credit is available and governance is accepted. It will be obtained on a **monthly** basis.
Type	Quantitative/Qualitative
Calculation / methodology	

Data source	Registered in the Mobile App
Required data points	Which data measurement or values are required.
Unit	%
Relation to target	Functional performance / auditability of the Mobile App

The KPIs for the BEMS are described in Table 43.

Table 43 - BEMS Key Performance Indicator description, calculation methodology and relevant characteristics.

KPI_BEMS_1	
KPI name	**Delay/latency in data collection**
Definition	The amount of time it takes the BEMS for a data packet to travel from a source node to a different destination node.
Type	Quantitative
Calculation / methodology	Difference between the time registered for both nodes.
Data source	-
Required data points	-
Unit	ms
Relation to target	BEMS functional performance evaluation

Economic Key Performance Indicators

The economic KPIs are important to know which are the reduction in energy cost that the GENTE solutions can achieve, as well as to evaluate the project from an economic perspective. The KPIs included in Table 44 are included.

Table 44 - Economic Key Performance Indicator list for assessment.

KPI ID	KPI Name
KPI_EC_1	Energy Cost Savings
KPI_EC_2	Payback Period

Table 45 includes a detailed description of these economic KPIs:

Table 45 - Economic Key Performance Indicator description, calculation methodology and relevant characteristics.

KPI_EC_1	
KPI name	Energy Cost Savings
Definition	The amount of money saved on energy bills due to energy-saving measures per month
Type	Quantitative
Calculation / methodology	$P_{CS} = C_{cons,0} - C_{cons,opt} = P_{cons} * (E_{cons,0} - E_{cons,\,opt}) * t_M$ $t_M = O_h * O_D$ where P_{CS}= Total monthly cost savings at household or LEC [€/month] $C_{cons,0}$= Total monthly cost of original energy consumption at household or LEC [€/month] $C_{cons,opt}$ = Total monthly cost of new energy consumption at household or LEC [€/month] P_{cons}= Energy price [€/kWh] $E_{cons,0}$ = Total original consumption in the household/LEC [kWh] $E_{cons,opt}$ = New energy consumption in the household/LEC (with the optimisation algorithms GENTE) [kWh] t_M= Monthly operational time [h] O_h= Daily Run Time [h/day] O_D= Operating days per month [day]
Data source	Measurements, calculated values, and current prices of emission sources.
Required data points	Energy consumption measurements Calculated values of operational time, values of energy cost of previous source, and values of current cost of the new energy source. Prices of current energy sources.
Unit	€/month
Relation to target	Quantification of energy cost savings
KPI_EC_2	
KPI name	Payback Period
Definition	The amount of time it takes to recoup the investment in energy-saving measures through energy cost savings.
Type	Quantitative

Calculation / methodology	$PB = \frac{C_0}{P_{CS}}$ where PB = Payback period [year] C_0 = Total initial investment costs [€] P_{CS}= Total annual cost savings [€/year]
Data source	Calculated values
Required data points	Initial investment for improving the energy consumption Total annual cost savings
Unit	year
Relation to target	Project economic feasibility

Comfort Key Performance Indicators

The thermal comfort KPIs are listed in Table 46.

Table 46 - Comfort Key Performance Indicator list for assessment.

KPI ID	KPI Name
KPI_CO_1	Thermal comfort level
KPI_CO_2	Thermal discomfort duration

The thermal comfort key performance indicators are described in Table 47.

Table 47 - Comfort Key Performance Indicator description, calculation methodology and relevant characteristics.

KPI_CO_1	
KPI name	Thermal comfort level.
Definition	Time during which the actual operative temperature exceeds the specified range during occupied hours is weighted by the number of degrees by which the range has been exceeded.
Type	Quantitative
Calculation / methodology	The proportion of the occupied hours during which the temperature lies outside the acceptable zone. The comfort indices will be calculated in the worst places of buildings (regarding summer comfort e.g. under the roof) simulated with free evolution of temperature. EN 15251 standard specifies that a building can be

	non-comfortable for 5% of its occupation hours per day. The index to compute is the number of days with more than 5% of time being uncomfortable. $deviation^i = \frac{\sum_j^{time} (t*\lvert comf_j^i - comf_{setpointi}^{max,min}\rvert)}{time} * \frac{100}{comfort\ range}$ where: $time$ is the period while the comfort has been tested. t is the time period when there is NO comfort in the occupied zone. $comf_j^i$ is the comfort value for the instant j under the definition i. $comf_{setpointi}^{max,min}$ is the comfort max, min value under definition i. $comfort\ range$ is the amplitude of the comfort zone under the definition i. Within the standard EN 15251 there is a definition of acceptable time periods "out of comfort". This time period is fixed to 24 minutes every 8 hours (considered working time during the day). In the supposed case that the discomfort reached in this 24 minutes will be maximum (100%). **Set points**: The energy consumption for cooling and heating purposes obviously depends on the chosen set point temperatures: Winter: 22°C Summer: 24°C
Data source	Measurement
Required data points	Indoor air temperature (°C) Comfort range Minimum and maximum temperature values
Unit	-
Relation to target	Thermal comfort evaluation when the building is optimised
KPI_CO_2	
KPI name	Thermal discomfort duration.
Definition	Number of hours below or over a specified minimal or maximal discomfort temperature (related to the set point temperatures)
Type	Quantitative
Calculation / methodology	$discomfort^i = Sum\ of\ intervals\ t^k - t^{k-1}$ if $T(t^k) < T_{discomfort\_min}$ or $T(t^k) > T_{discomfort\_max}$ with T the indoor air temperature, $T_{discomfort\_min}$ and $T_{discomfort\_max}$ the minimal or maximal acceptable temperatures, and t the time.
Data source	Measurement
	Indoor air temperature (°C)

Unit	-
Relation to target	Thermal comfort evaluation when the building is optimised

Forecasting Key Performance Indicators

The forecasting algorithms are a fundamental piece of GENTE solutions, as the predicted outputs will be used by the energy management algorithms, so it is relevant to assess the accuracy and performance of these algorithms. The forecasting KPIs in Table 48 relate to the forecasting algorithms performance assessment.

Table 48 - Forecasting Key Performance Indicator list for assessment.

KPI ID	KPI Name
KPI_FO_1	Forecasting error

Table 49 describes the calculation methodology for the errors used as KPIs for forecasting performance assessment:

Table 49 - Forecasting Key Performance Indicator description, calculation methodology and relevant characteristics.

KPI_FO_1	
KPI name	Forecasting error
Definition	A calculation of the forecasting error, using a methodology that is appropriate to the forecast type and dataset
Type	Quantitative
Calculation / methodology	A choice of forecasting error methodology will be made based on the type of forecast in question. It is expected that error will be calculated according to standard metrics, e.g., mean absolute error, mean squared error, root mean squared error R-squared error.
Data source	Model test dataset (withheld during training). Performance is measured on accuracy of current and power forecast at point of measurement (module or array)
Required data points	Test set of current or power values, withheld from initial test data
Unit	The same as the predicted target (i.e. current/A or power/W)
Relation to target	Typically, smaller calculated error indicates better model forecast performance

Conclusion

The present document serves as a guideline for the validation process of GENTE. The document describes the validation methodology that has been developed for GENTE, consisting of three levels: functional performance tests to verify the correct integration of the new hardware, the evaluation of the accuracy of the forecasting algorithms, and the test cases to validate GENTE objectives. This methodology is enriched with a social assessment to evaluate the impact of the user-engagement and the developed co-design process.

A detailed description of the tests to be conducted in every GENTE pilot is provided. For each test, the objectives, described steps, requisite, calculated KPIs, measured variables and assumptions are listed.

Finally, the Key Performance Indicators are described, provisioning the calculation methodology and the baseline. The KPIs have been defined for different domains: energy, environmental, forecasting accuracy evaluation, thermal comfort, economic, technical and social.

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