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Swiss Federal Office of Energy SFOE
Energy Research and Cleantech Division

Interim report dated 18 November 2022

GENTE

Distributed Governance for green ENergy communiTiEs

Source: ©GENTE, 2022

Date: 18 November 2022

Location: Bern

Publisher:
Swiss Federal Office of Energy SFOE
Energy Research and Cleantech
CH-3003 Bern
www.bfe.admin.ch

Co-financing:

ERA-Net Smart Energy Systems

The Scientific and Technological Research Council of Turkey (TÜBITAK)

Centro para el Desarrollo Tecnologico Industrial E.P.E. (CDTI)

Swedish Energy Agency Federal Department of the Environment, Transport, Energy and Communications (DETEC)

Swiss Federal Office of Energy (SFOE)

Subsidy recipients:
Lucerne University of Applied Sciences and Arts
Technikumstrasse 21, CH-6048 Horw
www.hslu.ch/iet

SmartHelio Sarl
Chem. de la Dent d'Oche 1b, 1024 Ecublens
https://smarthelio.com/

Authors:
Benjamin Bowler, Lucerne University of Applied Sciences and Arts
Fabian Widmer, Lucerne University of Applied Sciences and Arts
Daniel Raimundo, Lucerne University of Applied Sciences and Arts
Yousra Sidqi, Lucerne University of Applied Sciences and Arts
Jo Harris, Lucerne University of Applied Sciences and Arts
Chris Young, Lucerne University of Applied Sciences and Arts

SFOE project coordinators:
Antonios Papaemmanouil, Lucerne University of Applied Sciences and Arts,
Antonios.papaemmanouil@hslu.ch

SFOE contract number: SI/502312-01

The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.

Zusammenfassung

Das Ziel des GENTE Projektes ist es, ein Toolkit für Energie-Gemeinschaften und deren Manager zu erstellen. Das Toolkit soll eine Optimierung der Nutzung von Energieressourcen innerhalb der Gemeinschaft ermöglichen und das Erstellen von neuen Energie-Gemeinschafften durch verschiedene neue Geschäftsmodelle und Dienstleistungen fördern. GENTE untersucht die Anwendungsfälle von Energie-Ressourcen Integration innerhalb von Energie-Gemeinschaften, Prosumer Energie- und Servicemanagement - Verträge, sowie die Überwachung / Kontrolle der Energie-Ressourcen durch den Gemeinschafts-Manager. Die Innovation in GENTE umfasst Edge Intelligence, IoT-Plattformintegration, KI-Ressourcenoptimierung, Blockchain-Integration für Vertragsabschlüsse, Asset-Aggregationsmodelle und sozialwissenschaftliche Forschung.

GENTE startete am 01.Juni 2022 und befindet sich am Anfang der ersten Berichtszeitraumes in der "Anforderungen und Spezifikationen“ Phase. In diesem Zeitraum hat das Konsortium Fortschritte bei der Definition von Systemarchitektur und Datenmodellen, funktionalen Anforderungen, Systemspezifikationen und technischen Spezifikationen erzielt, eine erste Definition von Testfällen erstellt und erste Benutzerprofile erstellt. Darüber hinaus wurden erste Forschungen zu fortschrittlichen Last- und Erzeugungsprognosen auf Basis von KI-Techniken durchgeführt

Résumé

GENTE a pour but de créer une boîte à outils pour les communautés et les gestionnaires de communauté pour l’optimisation des ressources énergétiques et la fédération communautaire, et de promouvoir la création de nouvelles communautés grâce à de nouveaux modèles et services commerciaux. Les cas d’utilisation de GENTE sont l’intégration des ressources énergétiques communautaires, la gestion des contrats et des services énergétiques des prosommateurs et la surveillance et le contrôle des ressources énergétiques communautaires par l’intermédiaire du gestionnaire de communauté ou de fédération. L’innovation dans GENTE comprend l’intelligence en périphérie, l’intégration de plateformes IoT, l’optimisation des ressources par intelligence artificielle (IA), l’intégration de blockchain pour les contrats, les modèles de fédération communautaire / agrégation d’actifs et la recherche en sciences sociales.

GENTE a débuté le 1er juin 2022 et n’a donc pas encore terminé une période de rapport complète. Le projet est dans la phase « exigences et spécifications ». Au cours de la période visée par le rapport, le consortium a progressé dans la définition de l’architecture du système et des modèles de données, des exigences fonctionnelles, des spécifications du système et des spécifications techniques, il a créé une définition initiale des cas de test et a entrepris le profilage initial des utilisateurs. En outre, des recherches initiales sur les prédictions de charge et de production basées sur des techniques d’IA ont été menées.

Summary

GENTE will create a toolkit for communities and community managers for energy resource optimisation and community federation, and to promote the creation of new communities through new business models and services. GENTE use cases are for community energy resource integration, prosumer energy contract and service management, and monitoring / control of community energy resources through the community or federation manager. The innovation in GENTE includes edge intelligence, IoT platform integration, AI resource optimisation, blockchain integration for contracting, community federation / asset aggregation models, and social sciences research.

GENTE started on 01 June 2022, so has not completed a full reporting period. The project is in the ‘requirements and specifications’ phase. During the reporting period, the consortium has made progress in defining system architecture and data models, functional requirements, system specifications, and technical specifications, created an initial definition of test cases, and undertaken initial user profiling. In addition, initial research into advanced load and generation forecasts based on AI techniques was conducted.

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Abbreviations

ACF	Autocorrelation Function
AI	Artificial Intelligence
API	Application Programming Interface
DER	Distributed Energy Resources
DG	Distributed Generation
DLT	Distributed Ledger Technology
DMS	Distribution Management System
DSM	Demand Side Management
DSO	Distribution System Operator
EV	Electrical Vehicle
HP	Heat Pump
ICT	Information and Communications Technology
IoT	Internet of Things
LV	Low Voltage
LEC	Local Energy Community
ML	Machine Learning
MPC	Model Predictive Control
MV	Medium Voltage
NWP	Numerical Weather Predictions
PCA	Pearson Correlation Analysis
PV	Photovoltaic
RES	Renewable Energy Sources
SCADA	Supervisory Control and Data Acquisition System
SM	Smart Meter
SME	Small to Medium Enterprise
TRL	Technology Readiness Level

1 Introduction

1.1 Background information and current situation

To achieve the ambitious goals of the Paris Agreement and enable an effective green energy transition, a paradigm shift is needed. Energy is at the core of our society and a transition in how energy is sourced, shared, and traded will involve all stakeholders from all sectors. Decentralised renewable energy systems are rapidly becoming a key part of the future energy system, with new models of integration into energy networks, and facilitated by digital technologies as well as new business models. In particular, the participation of citizens as partners in energy projects will transform the energy system, with Local Energy Communities (LECs) being a core enabling structure.

The European Commission's Clean Energy Package confirms the prominent role LECs will play in the energy system; however, their economic, environmental, and social potential can only be realised through the adoption of new technology and systems that are underpinned by practical, human-centric support. Locally, the Swiss energy landscape must shift towards a higher penetration of renewables to meet the goals of the Energy Strategy 2050. An impulse towards this shift was given by a recent law reform which introduced the so-called “Zusammenschluss zum Eigenverbrauch” (ZEV) as a possible embodiment of local energy communities [1].

It is in this context that the GENTE project was conceived. GENTE will create a toolkit for communities and community managers for energy resource optimisation and community federation, and to promote the creation of new communities through new business models and services. GENTE has a strong relevance for the Swiss Energy Strategy 2050, the digitalisation strategy [2], and the SFOE energy research concept [3].

Research in decentralised approaches to LEC optimisation and control has the potential to help maintain a balance regarding supply and demand in energy networks for electricity, heating, and cooling, using socially acceptable technological paths. Further research is necessary to ensure reliable, optimised interaction of electrical, thermal and gas networks, buildings, local energy generation and feed-in, storage and distribution, in particular with regard to the load and provision flexibility of a site or its individual buildings for the electrical or thermal grid as well as the distribution of these flexibilities (over time and space), and the extent to which innovative information and communications technology (ICT) solutions can be applied in this respect.

Artificial intelligence plays a central role within GENTE. Of notable importance is the use of privacy preserving approaches to build forecasting models for consumption and production at the level of LECs and federations. This will allow the LECs and the federations to better discover and exploit flexibilities, translating into a more effective planning and optimisation for community energy goals.

The transition towards a renewable, secure and efficient energy system will be enabled by markets, policies and institutions designed to support energy efficiency and a shift towards renewables in a way that is efficient, broadly accepted, and facilitates individual well-being [3]. Research is required that can bring about a better understanding of the behaviour of the various actors, of their response to policy measures, and of the way the markets function.

In summary, GENTE provides a holistic approach to operate and promote LECs, including a governance toolkit, decision tools, algorithms, IoT platforms and approaches from social/behavioural sciences which boost the possibilities and motivation for stakeholders to participate in LECs. GENTE adds a layer on top of the LECs to enable federations of communities, which will make it possible to coordinate several communities in a broader network, thereby optimising the grid and enabling new business models.

1.2 Purpose of the project

To address and support successful engagement of citizens in the energy transition through the LEC, GENTE creates a distributed governance toolkit for LECs comprising technology for resource optimisation and human-centric protocols for successful realisation in the community. The need owners are prosumers, community managers, aggregators, municipalities, and distribution system operators (DSOs).

GENTE use cases are for community energy resource integration, prosumer energy contract and service management, and monitoring / control of community energy resources through the community or federation manager. The innovation in GENTE includes edge intelligence, IoT platform integration, AI resource optimisation, blockchain integration for contracting, community federation / asset aggregation models, and social sciences research.

To achieve its goal, the GENTE consortium integrates emerging technology, cutting edge applied research, strong links to need owners, social science expertise and expertise on commercial exploitation of project outcomes. Partner expertise includes IoT platforms, artificial intelligence applications in energy systems, distributed ledger technology (DLT), advanced sensors, smart devices, modelling and optimisation in intelligent energy systems, and social sciences. Links to need owners are provided by partners Troya (community), CELL (municipality, energy community), and Alingsås Energi (DSO).

GENTE develops energy community-oriented optimisation solutions for the LEC, focusing on consumer demand, heat pumps, buildings, renewable energy sources (RES), electrical vehicles (EVs), and storage. The project creates cutting-edge generation and consumption forecasts based on data analytics, while implementing intelligent decentralised control schemes through advanced edge computing, without compromising data privacy and cybersecurity. Advanced data collection and analysis algorithms support solutions for optimal energy utilisation via IoT, edge and platform-based tools. GENTE scalable solutions facilitate orchestrated operation of assets within and across communities, based on a cross-functional IoT platform, identity management, edge computing and blockchain technologies, bringing intelligence to distributed physical assets.

GENTE deploys an advanced energy IoT platform for real-time monitoring and control of LECs as well as facilitating communication to grid operators' control systems (e.g., SCADA/DMS). The IoT platform acts as the backbone for developed integrated solutions, as it gathers high-quality data, incorporating forecasting algorithms, optimisation, and control strategies for LECs and associated services by LECs (e.g., peak load control by heat-pumps/buildings). The reliable bi-directional communication enhances systems' resilience, allowing users to manage all energy-related services, providing both an individual and collective view using a single account platform. Overall, end users' smart meters, the grid and smart contracts for automatic energy exchange and flexibility services are interconnected via the identity system that facilitates communications between end users and the grid.

GENTE formulates a decentralised monitoring and control system for LECs and their integration in larger scales, allowing the community manager to monitor or federate community assets, calculate the available flexibility, determine the financial status, and to interact with community members and external actors. Then, the federation manager monitors the activity of the energy communities, interfacing with external markets as well as communities' assets. The developed algorithms will be tested in at least one of the three demonstration sites to identify the bottlenecks for a wider roll-out. Privacy and data security will be ensured through the governance models enabled by DLT.

1.3 Objectives

GENTE will create a toolkit for communities and community managers for resource optimisation and community federation, and to promote the creation of new communities through new business models and services.

To achieve these above goals, the following technical objectives (TOs) and non-technical objectives (NTOs) are defined within GENTE:

- **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 proving 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.

Technical KPI's are defined in Table 1.

Table 1 – GENTE Technical Key Performance Indicators (KPI)

#	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/simulations

2 Description of facility

GENTE provides a good representation of LECs with six 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.

Demonstration sites include

i) CELL Living Lab/Am Aawasser (Switzerland): A living lab with a “self-consumption community” that provides a test facility, equipped with PVs, EV charging, smart grid hardware-in-the-loop test lab, etc.; and which can be combined with the HSLU campus.

ii) Luzern Sued (Switzerland): An early-stage cross-community mixed site that comprises six urban areas around HSLU campus, which can be used to implement and evaluate co-design practices in a new energy community setting.

iii) HSB Living Lab (Sweden): A residential building on the premises of Chalmers campus equipped with PVs, batteries, heat pumps, EV chargers and other controllable resources (washing machines, dryers, etc.).

iv) Alingsås Energy grid (Sweden): A distribution network with increased installation of PVs and heat pumps with energy storage of heat.

v) Troya Cooperative (Turkey): A residential energy community equipped with large PV installations and heat pumps.

vi) Troya cooperative island energy community (Turkey): An energy community on an island that is suitable for the demonstration of federations of communities, which is under development and expected to be formally established in early 2023.

Detailed site characterisation is underway and will be published during the next reporting period.

3 Procedures and methodology

GENTE’s consortium consists of a well-balanced composition of academic partners, SMEs (technology providers/developers) and large industrial partners (DSOs) with complementary competences and capabilities to deliver the project ambitions.

GENTE adopts a mission-based approach (Figure 1).

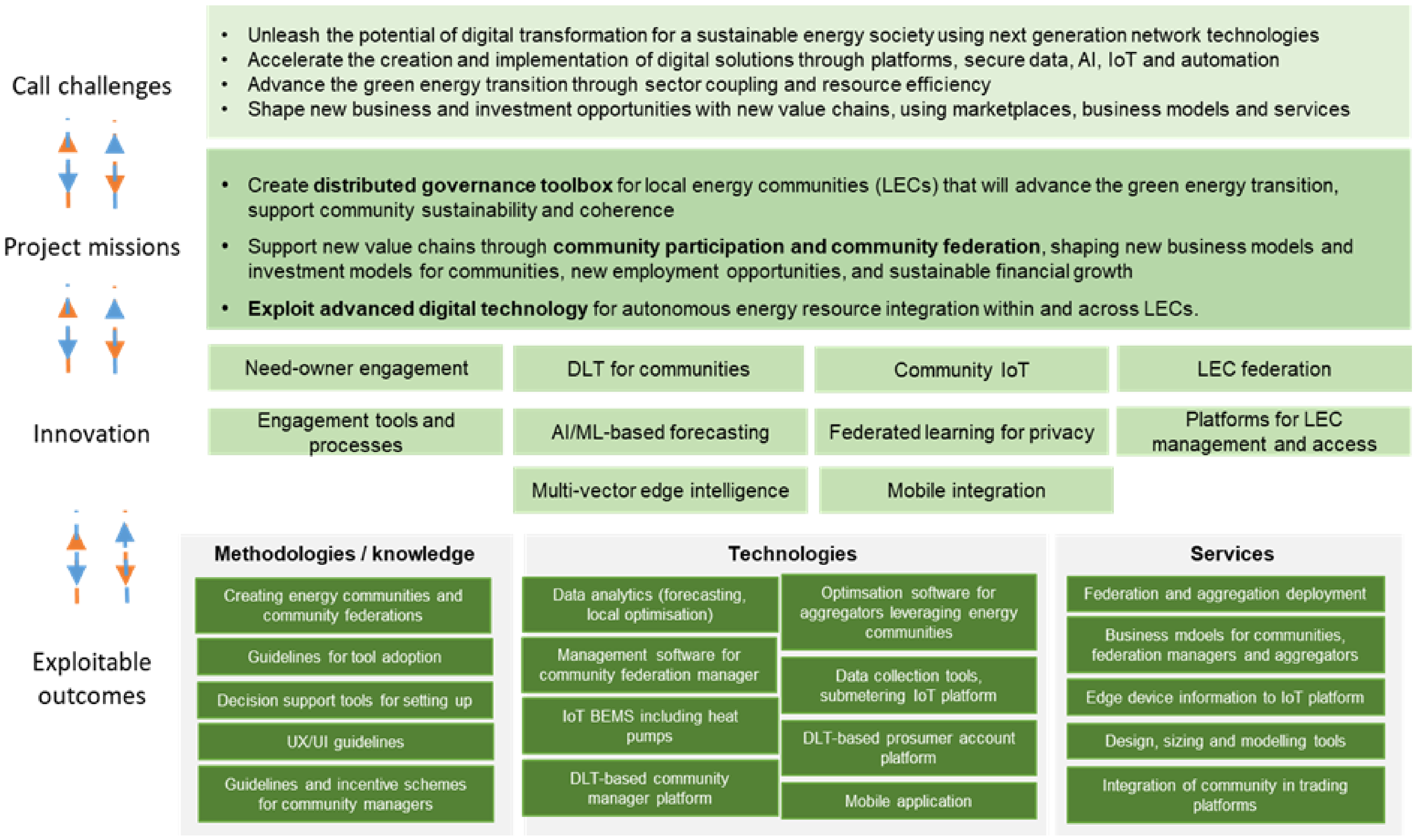

Figure 1 – GENTE mission-based approach (challenges, missions, innovation, and exploitable outcomes)

GENTE is organised along nine work packages, belonging to four broad categories: WPs 1-2 include project management and knowledge community building; WPs 3-4 deal with the specification of need owners and related use cases, as well as the behavioural studies to develop tailored business models targeting market uptake and scalability of the exploitable results of the project. WPs 5-8 will develop the technical framework, which is the backbone of the GENTE platform. This will include edge intelligence and data analytics (WP5), optimisation algorithms and services for LECs (WP6), aspects of cybersecurity and identity management and their bundling into a governance framework (WP7) and the coordination of all these parts within an IoT platform, which will then be deployed. The last, crucial work package focuses on the deployment of the developed system within living labs in different countries (WP9). The work package structure is shown in Figure 2. At a high level, partners are responsible for scope as follows:

- Lucerne University of Applied Sciences (HSLU) provides competences in LEC, IoT, AI, edge, and federated analytics. In addition, the Institute of Sociocultural Development brings expertise in evaluation of community development processes, engagement and adoption in energy and social science data analysis. CELL, Luzern Sued and Am Aawasser are demonstrators.
- Chalmers University of Technology (Chalmers) develops a building energy management system from previous projects within communities for energy optimisation and provision of flexibility to DSOs. HSB Living Lab is a demonstrator.
- ES Systems AB, part of Energy Save Group (ES) contributes with development and control of heat pumps, enabling integration into LEC and smart buildings. ES will demonstrate the functionality of heat-pump systems connected in the local energy community in Alingsås distribution network.
- Alingsås Energi Nät AB (AE) provides a demonstrator in Alingsås in Sweden to show how to develop a sustainable energy society through cooperation between the LEC and suppliers of heat pumps, energy storage and equipment for measurement, analysis, and control to achieve increased flexibilities, energy efficiency, and reduced CO_2.
- Prosume Solutions SL (PRO) provides solutions for DLT applications in the energy sector, develops cybersecurity and identity management modules and distributed governance tools, designs mobile-first apps for user-engagement and data monitoring, coordination, and deployment of data licensing methods, and integrates the solutions into demonstrators.
- R2M Solution Spain SL (R2M) contributes with development of AI algorithms for energy optimisation in the LEC, individual controls based on reduced models, digital twins for buildings and energy models to support predictive controls; definition of business models, commercial exploitation and scalability for the market uptake of the GENTE solutions.
- SmartHelio (SH) provides IoT-based sensors for DER and conducts AI-enabled data analysis which can predict losses to optimise resources and improve energy forecasts.
- REENGEN (REE) develops a cloud-based Energy IoT Platform with Platform-as-a-Service data analytics solution for integration of distributed assets, data sources and stakeholders.
- Troya Renewable Energy Cooperative (Troya) is a member of Rescoop.eu and leader of Turkey’s Energy Cooperative network. Troya provides a demonstrator which will test GENTE’s solutions in communities.

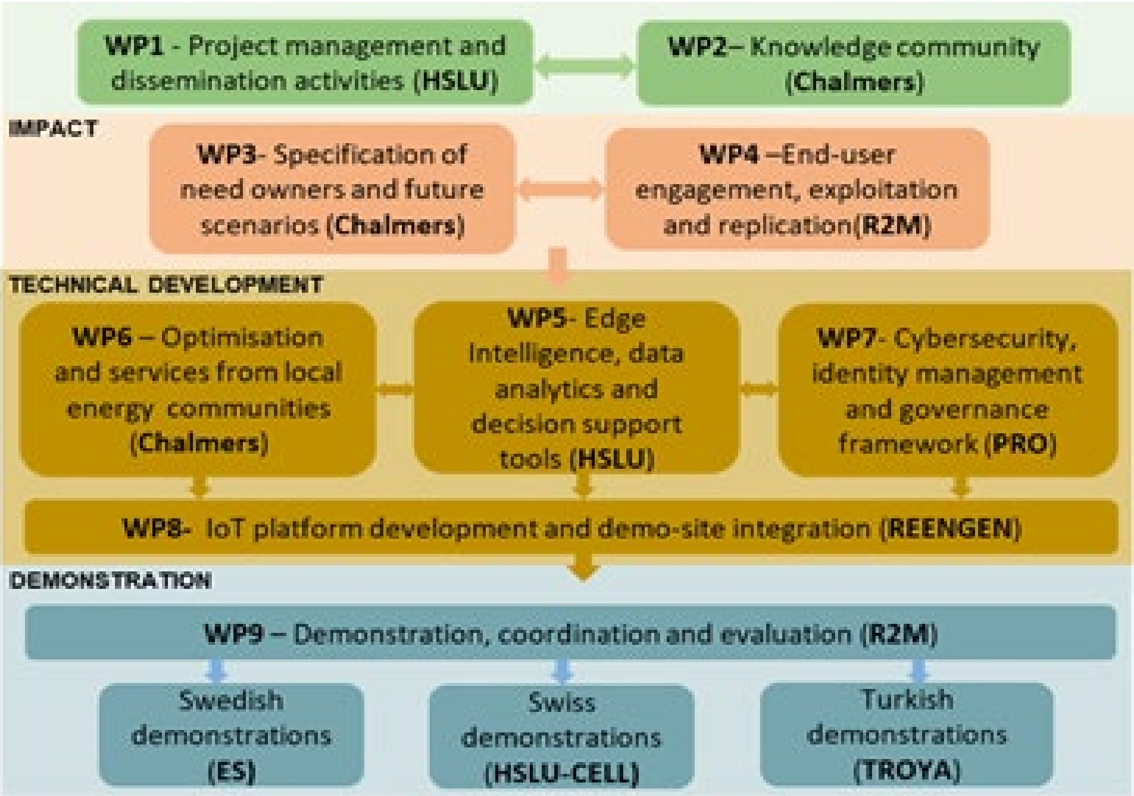

Figure 2 - GENTE work package structure

GENTE uses a multi-disciplinary approach for collaborative innovation, integrating research domains in several fields:

i) social sciences to map the needs and values of need-owners and to develop new business models.
ii) in smart grid technologies to develop energy optimisation in energy communities and development of IoT based energy community governance toolkit, including energy resource management and distributed ledger technologies; and
iii) in data sciences, AI methods for advanced forecasting, edge intelligence as an enabler for energy management and optimisation)

to push forward the practical implementation of energy communities.

GENTE solutions are first being developed by the academic partners and technology developers in the project. For co-creation and involvement, needs and preferences of end-users and other stakeholders will be identified using a combination of survey, interview, and experimental methods. The solutions will be validated first at the living lab levels, then at real full-scale environments to increase TRL levels of solutions. Once solutions have been validated, business models can be developed, and replicability and scale-up plans can be made to bring the solutions to the market.

4 Activities and results

4.1 Workflow during reporting period

GENTE started on 01 June 2022, so has not completed a full reporting period. No deliverables were due prior to the completion of this report. However, a summary of work completed to date is provided in this section.

A simplified project workflow is summarised in Figure 3, highlighting tasks that were initiated in the reporting period. The project is in the 'requirements and specifications' phase, defining system architecture and data models (Tasks 7.1, 8.1), functional requirements, system specifications, and technical specifications (Task 8.2), definition of test cases (Task 9.2), and initial user profiling (Task 4.1). In addition, initial research into advanced load and generation forecasts based on AI techniques was conducted (Task 6.1)

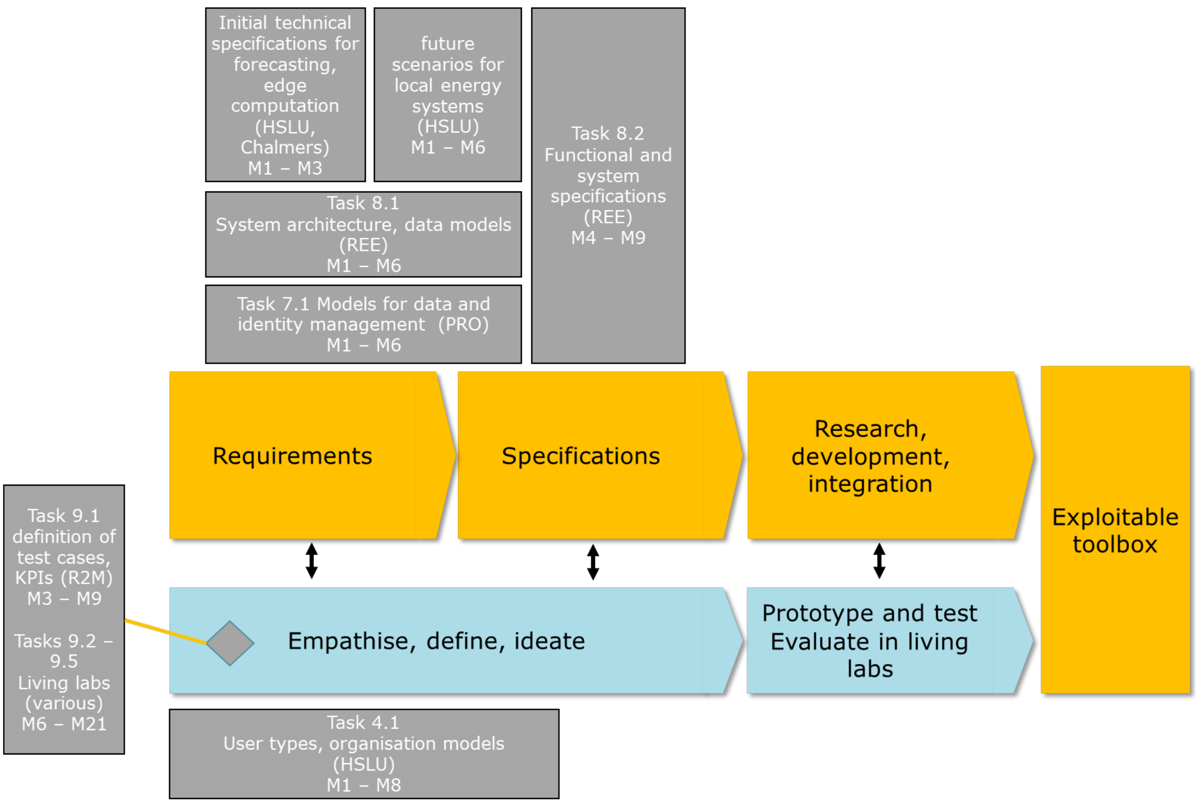

Figure 3 - Simplified initial workflow showing early tasks

4.2 Project Management and Knowledge community (WP1, WP2)

During the reporting period the Consortium Agreement was drafted by HSLU, finalised, and signed. Project governance and the operational framework were created, including a consortium handbook that comprised the data management plan, quality plan, and project risk register. A deliverable review plan and classification for public and internal deliverables was created.

The GENTE project brand identity, website[1] and templates were established, and the project factsheet and profile were created on the EXPERA platform in line with ERA-NET requirements. Consortium members participated at ERA-NET events.

4.3 Specification of future regional scenarios for local systems with high renewables (WP3)

A literature review was initiated by HSLU to study scenarios for future growth and development of local energy communities in Switzerland and across Europe. The purpose of the review is to characterise market potential for the GENTE solutions, and to ensure that research and technical development closely meets the needs of future local energy communities. Approximately 1000 papers were initially identified, shortlisted to around 250 relevant papers, then further screened and progressed to full text review of 15 to 30 papers. Results of the literature search will be available during December 2022.

In addition, a review of definitions of EU definitions of energy communities was conducted and mapped to the GENTE test sites.

4.4 End user engagement, exploitation, and replication (WP4)

A literature search was conducted by HSLU for literature on profiles, practices, and attitudes of LEC participants (prosumers etc.), resulting in 22 relevant articles. The review of these articles is ongoing. First findings suggest that prosumers generally accept use of personal energy data (smart metering, metering on device level) and automation of household devices (as a means of load shifting), but that daily routines restrict the possible scope of automation and flexibility. Preliminary interview results seem to point in the same direction.

A second important activity was negotiating access to the primary research site in Switzerland - the residential development AmAawasser - which we consider to be an LEC within the project. Access was achieved in several steps. A relationship was established with the manager of the site and his assistant, who from a social science point of view are gatekeepers to the participants of the AmAawasser LEC. With their support, all households within the LEC were contacted, informed about the research project, and asked to participate in research activities relating to WP4. 10 out of 26 households have so far agreed to participate. At the time of this report, members of four of these households have been interviewed in semi-structured qualitative interviews.

A third activity was the topical and methodical preparation of the interviews. An interview guide (set of questions) was developed in cooperation between the social-science and some engineering members of the GENTE team, to ensure issues relevant to the technical design are approached in the interviews. Analysis of the interviews has just started, so results are to be expected later. These results will form the basis for further surveying.

4.5 IoT system development, edge intelligence, data analytics and decision support (WP5, WP8)

4.5.1 State of the art analysis

State of the art analysis was completed by HSLU for edge computation in existing resources, partner devices and emerging technology. The analysis included desktop research, literature analysis, and

[1] www.genteproject.com

discussions with GENTE technology partners. A map showing existing commercial products, and their relevance to GENTE, is provided in Appendix A.

4.5.2 System architecture

Research was started on edge intelligence for DER forecasting and diagnostics. An overall system architecture was defined by HSLU in collaboration with the IoT platform provider, REENGEN, and IoT device provider, SmartHelio (Figure 4). The architecture was defined according to:

- the specifications of the test fields in GENTE;
- the functionality and limitations of partner devices; and
- the features and technical objectives within the scope of work of the overall GENTE project.

REEGEN gateways will be used to interface with smart devices or distributed energy resources in the LEC. The hardware interface with smart devices will be specified by REENGEN, with this interface 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. The hub will manage optimisation across the community. Certain data will be encrypted and uploaded to the cloud, in accordance with the privacy protocols developed by Prosume. This data will be used as part of the contracting protocols, or to be displayed to users via the mobile app.

There will be variations to the architecture across different test sites. For example, in Am Aawasser, a local data collection and optimisation platform is already in place, meaning the focus for GENTE will be on improvements to LEC optimisation. In contrast, the Turkish sites currently have no optimisation in place, meaning the full architecture is likely to be deployed.

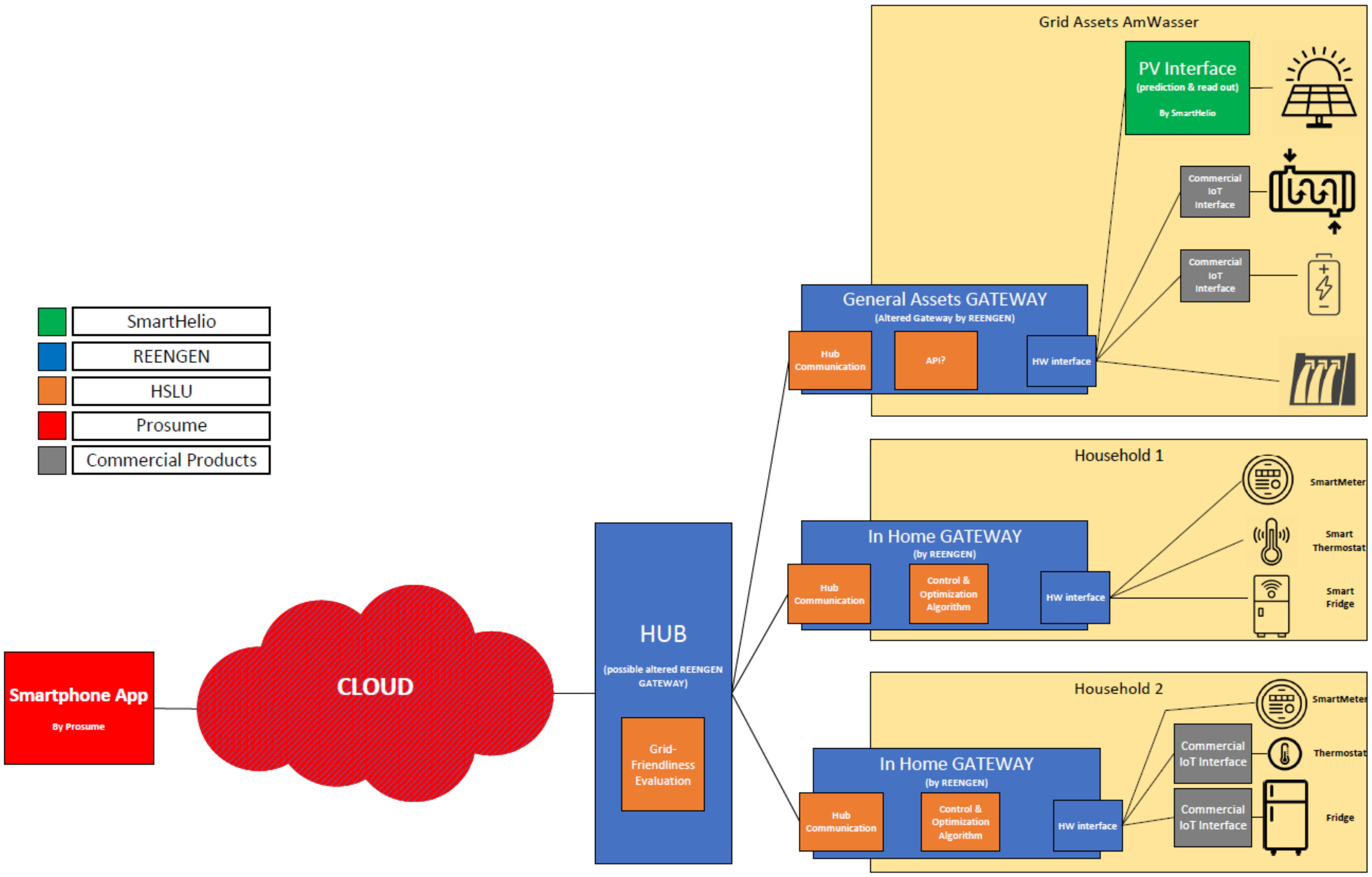

Figure 4 - Initial GENTE system architecture

4.5.3 Centralised optimisation algorithm

An analysis of literature was undertaken by HSLU to identify existing approaches to local energy community resource optimisation. Algorithms were identified as being relevant to GENTE if they:

i) Used predictions for production and consumption in the LEC.
ii) Were explainable (i.e., no black-box approaches).
iii) Were adaptable in terms of assets and model complexity, so they could be changed to fit the requirements of different communities; and
iv) Had limited computational requirements, indicating their potential suitability for edge implementation.

In the related literature, approaches were generally based on dynamic programming and reinforcement learning. A model predictive control (MPC) approach with a finite horizon was chosen as reinforcement learning is less well suited to the selection criteria identified above. Three main asset types (producer, storage, and consumer) were defined with basic attributes and interconnected with constraints (such as energy balance in the community, maximum power, availabilities, …), which could then be described as an optimisation problem through a series of constraints that are addressed for each time index in a finite time horizon. A first configuration is being established in a simulation tool.

A ‘grid friendliness evaluation’ was proposed as an initial optimisation target and developed at an OpenData hackathon [4]. To show customers their potential for behavioural changes, a simple score was calculated based on individual consumption patterns, the local renewable energy production, the national energy production, and the national energy consumption, with the intention of ranking individual grid users based on their relative behaviour. The goal of the score was to incentivise a change on user behaviour by being able to compare an LEC member’s behaviour to anonymised scores from their local community, their own scores from prior seasons, and a national score distribution. The score also provided the basis for a dynamic tariff, which changes based on the end users’ behaviour. It employs a linear combination of weighted “sub-scores”, each representing one of the components described.

Further research will be conducted to select the most suitable optimisation algorithms.

4.5.4 Development of a prototype object-oriented simulation tool

An object-oriented simulation tool for energy resource optimisation has been developed by HSLU in its ongoing research on eMobillity. The tool is highly relevant to GENTE and has been adopted with two goals: i) provide an environment to implement and test the functionality of the proposed algorithms and ii) serve as a demonstration tool for local communities, highlighting the advantages of smart control of their assets.

In the backend, the number of assets can be freely chosen, and characteristics can be individually specified. The data loader is abstracted from the main code to simplify the ingestion of site-specific data, allowing open-source data to be replaced with community-specific data from GENTE test sites when it becomes available. Based on the (flexible) load profiles of the consumers, the storage characteristics (capacity, rated powers, efficiency, and availability), the predicted energy generation of the local producers, and the external grid (dynamic) pricings and limits, a linear program solver computes the optimal load schedule with respect to a specific objective function (e.g., minimising cost or maximising self-consumption).
For the demonstration requirement, an enhanced web frontend, with more predefined values, is being developed. Planned future enhancements include designing a default process for cases where solving

the problem is infeasible (e.g., not enough energy available to fulfil consumption), including carbon footprint as a metric, and integrating building heat systems with the same production / storage / consumption asset types, with their specific electrical characteristics.

Once prototpying is complete, the algorithms will be adapted to function on the REENGEN IoT gateway or community cloud platform.

4.6 Optimisation and services from local energy communities (WP6)

In the first task associated with WP6, Chalmers initiated research into advanced load and generation forecasts based on AI techniques, initially targeting energy assets at the Chalmers campus.

Chalmers campus has 831 kW of total solar power. The PVs are mainly installed on the rooftops of Chalmers office buildings and lecture halls. The historical data of the PVs and electrical loads are measured and stored by the Chalmers-emulated IoT platform. Forecasts are conducted in time steps of 1 hour and with two horizons of 1 hour and 24 hours ahead.

To develop the forecasting tool, potential features for the machine learning methods were identified, and then, based on feature engineering, the features with the highest correlation were selected. The features which can be candidates for the ML algorithm for PV generation forecast can be categorised into three groups: calendar features, meteorological features, and historical features. Calendar or time features including an hour of day and month reflect the seasonality and the daily pattern of the PV output. Meteorological features such as downward solar radiation, temperature, humidity, wind direction, and speed, affect the output power of the PV plant. The previous timestep data of the PV output can have a high correlation with the predicted sample.

Weather features were retrieved from the rebasing energy weather application program interface (API) [5] . The API serves endpoints from different numerical weather predictions (NWPs) and models. Based on the geographical coverage and resolution, candidate NWPs were selected to collect the weather predictions. Finally, with respect to the accuracy of the forecasts, delivery delay, and update cycle of the NWP models, the MEPS1 (The MetCoOp Ensemble Prediction System) model was utilised to collect historical weather predictions as well as the real day ahead weather predictions for the implementation of the forecast tool. It should be noted that due to limited access and proximity of the PV sites to each other, the weather features were collected for a location in the centre of the Chalmers University of Technology and used for all PV sites.

Eight weather features including cloud cover, pressure, relative humidity, solar downward radiation, temperature, total perception, wind direction, and wind speed were obtained by the NWP model. To determine the relationship between PV generation and the individual weather features, Pearson Correlation Analysis (PCA) was employed [6]. To determine the time steps features, a sample autocorrelation function (ACF) was used as the technique to compute the correlation of the solar power data between the current time and different lagged points in time. Accordingly, it was noticed there is a high correlation of solar power generation between the current time step and the 1-hour and 2-hour lagged points in time. Based on the feature engineering, the best features were selected for 1-hour ahead and 24-hour ahead time horizon forecasts.

Chalmers loads are mainly office buildings and their historical data of them are collected to train models. The approach taken for load forecasting is like PV forecasting. Feature engineering for the load prediction was conducted by the PCA method as well. The results indicated that weather features have a low correlation to the load and only the historical data and Calendar features were utilised for the prediction of the load.

4.7 Demonstration, coordination, and evaluation (WP9)

A template was created by R2M to define initial test cases for field trials. At the time of writing this report, the work has not been finalised. Further details will be published in the next annual report.

5 Evaluation of results to date

No project results were released during the reporting period; this section is therefore not relevant.

6 Next steps

Significant progress is expected during the next reporting period. A summary of deliverables scheduled for release is provided in Table 2. Project milestones planned during the next reporting period are provided in Table 3.

Table 2 - Deliverables scheduled for release during next reporting period

Deliverable, # and Name		Lead	Review	Type	Class.	Del M	Deadline DD/MM/YY
1.1	Project handbook (incl. quality/risk data financial plan, protocols, and KPI dashboards)	HSLU	Chalmers	R	C	4	25/11/22
7.1	Guidelines and requirements, initial set of smart rules and related ontology	PRO	REENGEN	R	PU	4	25/11/22
1.2	Communication, dissemination, and exploitation strategy	HSLU	Chalmers	R	C	6	23/12/22
3.1	Future scenarios of local energy systems with increased renewable share	HSLU	R2M	R	PU	6	23/12/22
4.1	Identification of user types and organisational models	HSLU	Prosume	R	PU	8	15/02/23
6.1	Advanced load and generation forecast	Chalmers	HSLU	R	C	9	15/03/23
8.1	Definition of system architecture and specification of functional requirements	REENGEN	Prosume	R	PU	9	15/03/23
9.1	Test cases, assessment framework and KPIs	R2M	REENGEN	R	C	9	15/03/23
7.2	Validation of DLT and GDPR compliance legal rules	Prosume	R2M	R	C	11	15/05/23
2.1	Annual reporting	Chalmers	HSLU	R	ERA	12	15/06/23
2.3	Annual project event	Chalmers	HSLU	R	ERA	12	15/06/23
3.2	Specification of relevant need owners	Chalmers	R2M	R	PU	12	15/06/23
4.2	End-user engagement and community benefits based on survey and interview data	HSLU	R2M	R	C	14	01/09/23
3.3	Definition of highly applicable use cases	R2M	HSLU	R	PU	15	15/09/23
4.3	Market and stakeholder analysis with evaluation and exploitation roadmap	R2M	HSLU	R	C	15	15/09/23
5.1	Adaptable sub-metering device for intelligent community energy resources	SH	REENGEN	R	C	15	15/09/23
5.2	Edge-based DER forecasting and diagnostic algorithm, incl. privacy-preserving learning	HSLU	Chalmers	R	PU	15	15/09/23
6.2	Advanced BEMS for “Building control as a service”	Chalmers	Energysave	R	PU	15	15/09/23
8.2	Development of GENTE cross functional platform	REENGEN	HSLU	R	PU	15	15/09/23

Table 3 - Milestones to be completed during next reporting period

Milestone # and Name		M
5.1	Research complete - clear solution proposed for sub-metering device	10
3.1	Identification of relevant need owners completed	12
5.2	Device hardware and software functional prototype available for field testing	15
6.1	Advanced BEMS operational	15
5.3	Digital twin integration of data from functional prototype edge device	18
8.1	IoT-platform operational and integrated in all demonstration sites	18
9.1	GENTE solutions deployed in all living labs	19
4.1	Workshop for boosting the scalability and replicability of GENTE solutions	21
6.2	Toolbox for distributed governance of energy community completed	21
9.2	GENTE living labs validation and assessment completed	24

7 National and international cooperation

During the reporting period, partners met face to face once for an international kick-off meeting, and continue to meet at least monthly during regular, planned, work package leader meetings. Bi-lateral discussions take place regularly between partners to progress individual tasks.

ERA-NET mandates participation in EXPERA (Knowledge Exchange) activities and the completion of project communication and dissemination tasks. All requirements have been met by the consortium during the reporting period.

An international advisory board has been established and will meet for the first time during Q1/2023.

8 Communication

This section only applies to flagship projects and so has not been completed.

9 Publications

There were no publications during the reporting period.

10 References

[1] S. F. O. of E. SFOE, 'Leitfaden Eigenverbrauch', Jul. 2021.

[2] Federal Office of Communications OFCOM, 'Digital Switzerland Strategy', 2016. [Online]. Available: https://www.bakom.admin.ch/dam/bakom/en/dokumente/bakom/digitale_schweiz_und_internet/Strategie%20Digitale%20Schweiz/Strategie/Strategie%20Digitale%20Schweiz.pdf.download.pdf/digital_switzerland_strategy_Brochure.pdf

[3] 'Energy research Masterplan of the Federal Government 2021–2024', Federal Energy Research Commission CORE, Bern, Sep. 2020. [Online]. Available:

https://www.bfe.admin.ch/bfe/en/home/forschung-und-cleantech/forschung-und-cleantech1.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZW4vcHVibGljYX/Rpb24vZG93bmxvYWQvMTAzMjg=.html
[4] ‘eco-friendliness score - Energy Data Hackdays 2022’. https://hack.opendata.ch/project/836 (accessed Nov. 15, 2022).
[5] ‘The open and collaborative energy modelling platform’. https://rebase.energy (accessed Nov. 15, 2022).
[6] G. G. Kim *et al.*, ‘Prediction Model for PV Performance With Correlation Analysis of Environmental Variables’, *IEEE J. Photovolt.*, vol. 9, no. 3, pp. 832–841, May 2019, doi: 10.1109/JPHOTOV.2019.2898521.

11 Appendix A – Existing commercial solutions mapping to GENTE

Company	One liner	Open source or not-for-profit	LEC Target market			Offering - features									Offering - product					
			Community-led	Business-led	Not LEC specific	Data Analytics	Federation of Communities	Local Optimisation		User control		Visualisation		Contracting and Billing	Community platform / apps	Home energy mgt platform	Mobile app	IOT optimisation platform	Hardware – IoT gateway	Hardware – sub- metering
			Community coordinated	Centrally coordinated	Generic, adaptable platform	Energy, DER forecasting	Coordinate multiple communities	Assess and optimise community energy use and flows	Assess and optimise at building level	Enable members to choose energy / trading partners	Management software for community manager	Individual	Community manager	Smart Billing						
Grid Singularity	German company for analytics and smart billing	□	■	□	□	■	□	■	□	■	□	■	?	■	■	□	■	□	□	□
Barbara	Spanish edge computing platform, aimed at smart grids/energy production	■	□	□	■	■	□	■	□	□	■	□	■	□	■	□	□	■	□	□
Greencom Networks	German/French SW IoT platform for LECs.	□	□	■	□	■	■	■	■	■	■	■	■	□	■	■	■	■	■	□
City Energy Analyst	ETHZ open-source tool for analysis and optimisation of urban energy systems	■	□	□	■	■	□	□	□	□	□	□	□	□	□	□	□	□	□	□
ICT Group	Dutch IoT platform for energy monitoring and control	□	□	□	■	□	□	■	?	□	■	?	?	□	■	□	□	□	■	■
Axiomtek	Taiwanese company offering IoT gateways for microgrids	□	□	□	■	□	□	□	□	□	□	□	□	□	□	□	□	□	■	□
Veos Digital	Italian SaaS for energy communities	□	■	□	□	■	□	■	■	□	■	?	?	□	■	□	■	■	■	□
Entnrnce	Dutch SW for LEC, energy trading	□	□	■	□	□	□	■	□	□	■	□	■	□	■	□	□	□	□	□
Contel Smart	Israelian HW and SW for microgrids	□	□	■	□	■	□	■	□	□	■	□	■	□	■	□	□	□	?	?
Lumenaza	German SaaS for energy trading	□	□	■	□	□	□	□	□	□	■	□	□	■	■	□	□	□	□	□
Stem	US SW for forecasting and optimisation in microgrids	□	□	□	■	■	□	■	□	□	■	□	□	□	■	□	□	□	□	□
Regalgrid	Italian company providing HW & SW for LEC management	□	■	□	□	□	■	□	□	■	■	■	■	□	■	■	■	□	□	■
AlsoEnergy	US-based company providing HW&SW for aggregated residential	□	□	□	■	□	□	■	□	□	■	□	■	□	■	□	□	□	□	□
Elum Energy	French company providing HW&SW to improve solar auto consumption	□	□	■	□	□	□	■	■	□	■	□	■	□	■	□	□	□	□	■
Enel X Way	American HW+SW platform for optimised charging of EVs (no V2G)	□	□	■	□	■	□	□	■	□	□	□	□	□	□	□	□	□	□	■
JT IoT	High-level British IoT communication enhancement solution	□	□	□	■	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□
Hark Systems	British HW+SW solution for connectivity and monitoring of energy systems	□	□	□	■	■	□	■	■	□	■	□	■	□	□	□	■	■	■	□
Ileco	Belgian Web-based platform for managing LECs.	□	■	□	□	■	□	■	■	□	■	■	■	■	?	■	?	□	□	□
Exnaton	Swiss spinoff, offering a cloud solution for energy management in LECs	□	□	■	■	■	□	■	□	□	■	■	■	■	■	□	■	□	□	□