DELIVERABLE

6.1 Report on planned trial sites setup

Version 1.1

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1. Introduction

This report provides an overview of the strategic planning, technological frameworks, and implementation processes for the trial sites integral to the ECom4Future initiative. This project is an ambitious undertaking and involves multiple partners across Europe. It aims to develop and validate innovative, interdisciplinary approaches to energy management within local energy communities, leveraging advanced technologies like AI, IoT, and the FIWARE open-source platform. ECom4Future is rooted in the challenge of integrating increasingly decentralized and renewable energy sources into local energy systems. The project's primary goals are to design AI-driven solutions for optimized energy management, provide high-resolution energy profiles for informed decision-making, and foster active participation in energy communities. These objectives will be achieved through a series of trial sites that represent diverse geographic and regulatory environments across Europe, including Germany, Austria, Sweden, and Romania.

This report details the setup of these trial sites, which will serve as critical testing grounds for the project's innovative energy management solutions. Each trial site is designed to explore different aspects of energy community dynamics, from the technical integration of renewable energy sources and storage solutions to the socio-psychological factors influencing community engagement. The report provides an in-depth look at the infrastructure and technologies that will be deployed at these sites, including smart metering, high-resolution load monitoring, and market-based algorithms for energy flexibility exchange. The trial sites are not just technical installations; they are living laboratories where the interaction of technology, regulation, and human behaviour will be closely monitored and analyzed. This holistic approach ensures that the solutions developed within ECom4Future are not only technically feasible but also socially acceptable and legally compliant. The report also addresses the regulatory and legal frameworks governing these trial sites, which vary significantly across the participating countries. By navigating these complexities, ECom4-Future aims to create scalable and replicable models for energy communities that can be adapted to different contexts across Europe.

Community engagement is a critical component of the ECom4Future project. The report outlines strategies for involving local stakeholders at each trial site, ensuring that the solutions developed are tailored to the specific needs and expectations of the communities involved. This includes plans for workshops, surveys, and real-time feedback mechanisms that will inform the ongoing development and refinement of the project's technologies. Overall, this report serves as a foundational document that not only outlines the logistical and technical aspects of the trial site setups but also frames these efforts within the broader goals of the ECom4Future initiative. It reflects a careful balance of innovation, practicality, and community involvement, setting the stage for significant advancements in the way energy is managed and consumed within local communities across Europe.

2. Planned trial sites overview

The ECom4Future initiative encompasses four pilot sites across Germany, Sweden, Austria, and Romania, designed to validate innovative energy management systems and practices in diverse regional and operational contexts. These sites leverage cutting-edge technologies like the FIWARE platform, hardware-in-the-loop (HiL) test benches, high-resolution monitoring, energy flexibility markets, and local energy trading mechanisms to optimize energy production, consumption, and storage. In Germany, the RWTH Aachen site focuses on flexibility quantification, local markets, and real-time anomaly detection, while the WUNergy Energy Sharing Community pilots cooperative energy sharing models integrating FIWARE EMS. Sweden's Chalmers Campus explores self-sustaining energy solutions with Vehicle-to-Grid (V2G) technology, while the Jättesten Energy Community emphasizes inter-building energy exchange and solar optimization. Austria's TU Wien and TU

Graz focus on fault detection and system optimization for local energy communities, with the 3 pilots (Innovation district Inffeldgasse, Niedergrail and Mariatrost) showcasing mixed used districts, PV systems and storage, while FH Joanneum and FH Campus 02 demonstrate flexible energy solutions for laboratories. Romania's GreenMogo Energy Community operates as a zero-energy building, integrating advanced analytics and prosumer management under regulatory constraints. Together, these trial sites serve as living laboratories, blending technology, regulation, and community engagement to advance scalable, sustainable energy solutions for Europe. The summary of planned trial sites are summarised in **Table 1**.

Table 1. Planned trial sites overview

Country	Trial Site	Use case ID	Use cases title
Germany	Smart Buildings and Smart Energy Laboratories (RWTH)	UC_RWTH_01	Quantification and trading of flexibility
		UC_RWTH_02	Local flexibility market
		UC_RWTH_03	Real-time anomaly detection in energy systems
		UC_RWTH_04	Heat pump voltage control for Grid Support
	WUNergy Energy Sharing Community (SWW)	UC_SWW_01	Management of ESC via FIWARE EMS
		UC_SWW_02	Integration of Flexibility Aggregation and Trading via FIWARE EMS
		UC_SWW_03	Enhance Flexibility within Energy Sharing Community
Sweden	Chalmers Campus Energy Community (Chalmers)	UC_CHA_01	Energy Management for Academic Buildings
		UC_CHA_02	Local Energy Market and Flexibility Trading
		UC_CHA_03	Integration of Vehicle-to-Grid (V2G) Technology
	Jättesten Energy Community (Chalmers)	UC_JÄT_01	Energy Management for Residential Buildings
		UC_JÄT_02	Optimal Solar Energy Production and Storage
		UC_JÄT_03	Inter-building energy exchange
Austria	FDD and Optimization of Energy Community Campus Inffeldgasse (TUW / DiLT)	UC_INF_01	Fault detection and diagnosis for energy systems
		UC_INF_02	Energy consumption prediction for mixed use districts
	Energy Community Niedergrail (TUW / DiLT / dwh)	UC_EC_01	Demand side management for prosumers with flexible loads
		UC_EC_02	Demand side management for energy communities
		UC_EC_03	Demand side management for energy communities with dynamic pricing

	Energy Community Mariatrost (TUW / DiLT / dwh)	UC_EC_04	Electricity consumption forecasting
		UC_EC_05	Load profile disaggregation
	FH JOANNEUM & FH CAMPUS 02	UC_EAS_01	Energy Management for decentralized laboratories
		UC_EAS_02	Smart Hot Water Preparation
		UC_EAS_03	Intelligent room climate control
Romania	GreenMogo Energy Community (UPB)	UC_RO_01	Optimal operation of Prosumers with flexibilities (generation, storage, loads)
		UC_RO_02	Optimal operation of Prosumers within an energy community
		UC_RO_03	Data Analytics and Anomaly detection

2.1 Smart Buildings and smart Energy laboratories (RWTH)

This pilot aims to extend the I-Greta setup to reach a higher TRL, by incorporating flexibility markets and increasing the use of hardware-in-the-loop test benches in optimizations. Furthermore, for selected building energy systems (BES), a monitoring resolution of 1 reading/second is planned. The high resolution monitoring allows further demonstrations for anomaly detection in BES.

- Demo 1: Heat pump (HP) HiL thermal test bench (residential building): Participation in flexibility market
- Demo 2: Non-residential building: Participation in flexibility market
- Demo 3: HP HiL electric test bench(DC): voltage control in grids with a real HP and battery
- Demo 4: Air handling unit in a non-residential building: real-time probabilistic anomaly detection

Pilot Description

Background: Demo 1 and 2 investigate the ability of a typical residential and non-residential building to participate in flexibility/energy markets within an energy community. The different user needs for residential/-nonresidential are included. Demo 3 investigates voltage control for heat pumps (completely technical) to provide stabilizing services for the electrical grid. To monitor and check the stability of services and normal operation, demo 4 uses probabilistic models of a BES to detect anomalies in real-time.

Scope: The demos include a real heat pump (Demos 1 and 3) as well as a real building and an air handling unit (Demo 4), all located at the RWTH Aachen University. The rest of the EC will be simulated. Possible time frame for analysis ~ 1 week.

Target Energy Community: The two real systems describe a residential (SFH) and a non-residential (test hall) building located in Aachen. Other participants are simulated.

Energy consumption and production: Demo1 and 3 have a combined electrical consumption of ~60kW. Since the rest of the EC is simulated we can scale this as much as we want.

Technical Framework

Infrastructure and Technologies Used: Demo 1 and 2 will be using FIWARE. Demo 3 does not rely on communication infrastructure

Integration with Existing Systems: No real community is investigated

Data Requirements and Sources: The demos are monitored and data is utilized RWTH internally to analyze the demo results. Certain anonymous data sets can be shared with the partners.

Regulatory and Legal Considerations

There is no real energy community (EC) in this pilot, therefore EC-specific legal forms, requirements, and challenges do not apply.

Community Engagement

There are no engagement activities planned. The users of the test hall are the only included stakeholders, since every other system is simulated.

Use Cases for Demo Pilots

Use case ID: UC_RWTH_01 Quantification and trading of flexibility

Overview: The use case consists of the trial sites of the RWTH. Each trial site will calculate and predict available flexibility and share offers with a market

Objective: Demonstrate method to quantify and predict flexibility, show case prosumers active involvement in markets, investigate aggregation

Target users: Prosumer, consumer

Innovation: Enable households and consumers to actively participate in the energy flexibility market

Pre-condition / Requirements: Finish setups for trial sites, stress-test methodology, develop market connection

Success criteria: Flexibilities are predicted accurately, cost of flexibility is quantified and provide flexibility offers are traded

Expected outcomes: Simulation and real use case show that method works for estimation of flexibility offers

Use case ID: UC_RWTH_02 Local flexibility market

Overview: Simulative (+ real-world) investigation of market-based approaches on trading flexibility

Objective: Optimize flexibility exchange in respect to legal and social boundaries

Target users: Prosumer, consumer, SWW

Innovation: Market-based algorithm respecting current legal and social boundaries, real-world application.

Pre-condition / Requirements: Method for market-based algorithm

Success criteria: Flexibilities are successfully exchanged in simulation and real-world application

Expected outcomes: Flexibilities are successfully exchanged in simulation

Use case ID: UC_RWTH_03 Real-time anomaly detection in energy systems

Overview: Investigation of real-time probabilistic anomaly detection approaches

Objective: Early detection of irregular operation patterns to prevent energy loss

Target users: Building owners, operators, engineers, maintainers

Innovation: Flagging of anomalies based on conditional probabilities

Pre-condition / Requirements: High-resolution measurements

Success criteria: Faulty operation is correctly identified as anomalous

Expected outcomes: Early anomaly detection leading to early system repair or mitigation strategies. Eventually leading to improved energy efficiency and cost savings.

Use case ID: UC_RWTH_04 Heatpump voltage control for Grid Support

Overview: Investigation of the possibility to utilize HPs for voltage control in the power grid

Objective: Regulate the voltage at the local grid connection point active and reactive power

Target users: Building owners, operators, engineers, maintainers

Innovation: Utilization of HP for grid services (voltage control)

Pre-condition / Requirements: A test HP for experimentation

Success criteria: Control of active/reactive power of the HP

Expected outcomes: Test system showing a proof of concept for the voltage control.

2.2 WUNergy Energy Sharing Community (SWW)

Pilot Description

The Energy Sharing Community „WUNergy" is on the verge of becoming operational, currently utilizing licensed software to handle critical functions such as creating billing items, aggregating energy data, and managing energy flexibilities within the community. To enhance these capabilities, an Energy Management System (EMS) developed within this project is being considered as a potential replacement or an extension to the existing software. This transition aims to improve operational efficiency, provide advanced features, and better accommodate the growing needs of the Energy Sharing Community (ESC).

Scope: The pilot will focus on a real-world ESC comprising:

- 10 Households: Residential units contributing to and consuming energy within the community.
- 3 Guest Houses: Commercial entities that participate in energy sharing and consumption.
- 1 Brewery: A local business that both consumes energy and potentially supplies excess energy back to the community.

This diverse mix of residential and commercial participants provides a comprehensive environment to test and evaluate the functionalities of the EMS.

The ESC WUNergy initially consists of 14 members, including prosumers (entities that both produce and consume energy), consumers, and companies. Over the duration of the project, the community is expected to expand significantly, potentially growing to accommodate up to 80 members. The community is situated within the grid managed by the

Distribution System Operator (DSO) SWW and is overseen by SWW, ensuring alignment with local energy regulations and grid management practices.

Technical Framework

The pilot will leverage a combination of advanced technologies and robust infrastructure to ensure seamless operation and scalability. Key components include:

- *FIWARE Platform:* Utilized for its interoperability and ability to integrate diverse data sources and services, facilitating communication between different system components.
- *Virtualization/Simulation Environment:* Since the current ESC operates with licensed software, the FIWARE EMS will run in a virtual or simulated environment to enable parallel operations and comprehensive testing without disrupting existing functionalities.
- *Cloud and On-Premises Infrastructure:* A hybrid approach to infrastructure deployment ensures flexibility, reliability, and scalability. Cloud services may be used for data storage and processing, while critical operations remain on-premises for security and performance.

Integration with Existing Systems: The ESC WUNergy currently relies on licensed software for essential operations. To integrate the new EMS without disrupting ongoing activities:

- *Parallel Operation:* EMS will run alongside the existing licensed software in a virtual or simulation setup. This approach allows for real-time data synchronization and comparative analysis.
- *Data Interoperability:* Leveraging standards and APIs provided by FIWARE ensures that data flows seamlessly between the existing system and the new EMS.
- *Gradual Transition:* Functionality will be incrementally migrated to the EMS, allowing for testing, validation, and troubleshooting at each step to minimize risks.

Data Requirements and Sources: Effective energy management relies on accurate and timely data from various sources:

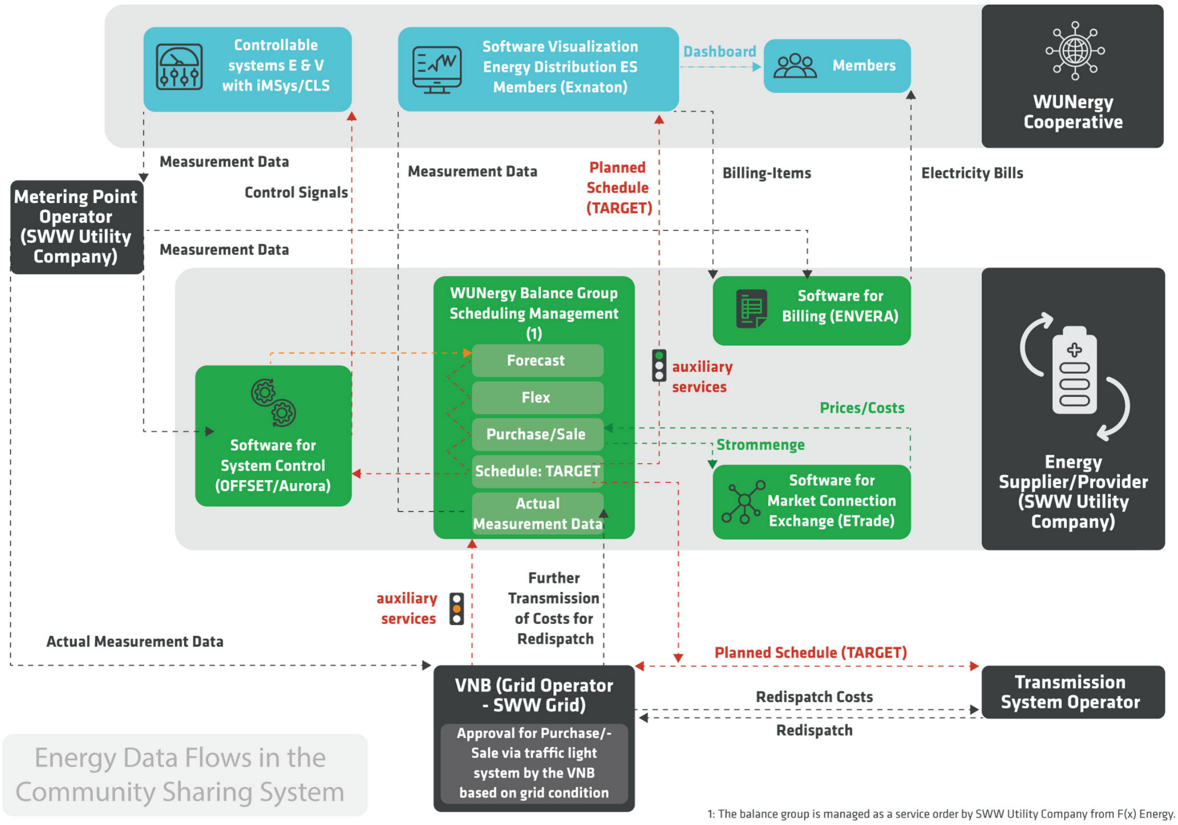

Figure 1. Abbildung 1 Software infrastructure and data flow of WUNergy

Currently running software at SWW:

Aurora by Offset Energy s.r.l.:

- Consumption Data: Detailed monitoring of energy usage across all households, guest houses, and the brewery. This includes real-time data collection and historical usage patterns.
- Production Data: Real-time data from PV systems and other renewable energy sources, tracking energy generation and availability.
- Prognosis for consumption and production
- Grid Data: Information from the DSO SWW regarding grid status, demand forecasts, and integration points for community energy exchanges.

Power Quartier by Exnaton AG

- Energy Exchange Records: Documentation of energy transactions within the community and with external entities, ensuring transparency and accountability.

Communication Protocols:

- IoT Devices: Deployment of smart meters and sensors to collect real-time data on energy production and consumption.
- Network Infrastructure: Reliable and high-speed communication networks to facilitate data transmission between devices, the EMS, and external stakeholders.

Regulatory and Legal Considerations

The ESC pilot operates under the legal form of an "Genossenschaft," which is a cooperative structure designed to facilitate the sharing of produced energy and energy flexibilities among its members. In this cooperative, all members—whether they are companies, prosumers, or consumers—enjoy equal rights, ensuring a fair and balanced participation in the community's activities.

Regarding compliance requirements, the pilot for Ecom4Future operates primarily as a simulation alongside its real implementation, which means that no specific regulatory compliances are necessary, except for ensuring data privacy. This focus on data privacy is crucial, given the sensitive nature of energy consumption and production data, as well as the potential for personal information to be involved.

One significant barrier is the prohibition or heavy restriction of peer-to-peer (P2P) energy trading in Germany. To navigate these challenges, WUNergy has strategically integrated and managed its operations through SWW, which serves as both the Distribution System Operator (DSO) and energy supplier. This approach helps to circumvent many of the legal and regulatory obstacles that typically hinder the development of energy communities in Germany, providing a practical workaround to support the pilot's objectives.

Use cases

Use Case UC_SWW_01: Management of ESC via FIWARE EMS

Overview: This use case involves the development and integration of an Energy Management System (EMS) to simulate and manage a local Energy Sharing Community (ESC). The integration aims to monitor and provide detailed data on energy production and consumption for each community member at 15-minute intervals. This information is essential for accurately tracking energy flows within the community and providing input for billing and energy management purposes. The data is shared with relevant systems for further processing.

Objective:

- Achieve compliance with German legal regulations for managing ESCs.
- Establish software interfaces between EMS and the software systems of Stadtwerke Wunsiedel (SWW), which manage energy distribution and billing.
- Provide accurate production and consumption data to enable the creation of billing items within the SWW ERP system.

Target Users:

- Prosumers: Community members who both produce and consume energy.
- Consumers: Members who primarily consume energy from the community.
- Small and Medium Enterprises (SMEs): Businesses participating in the ESC.
- SWW (Stadtwerke Wunsiedel): The energy supplier managing and overseeing the ESC.

Innovation: The setup creates a blueprint for managing ESCs for energy suppliers, enabling a scalable and efficient approach to energy sharing within communities. This use case also represents an innovative replacement for existing licensed software, offering more customized and integrated management for ESCs.

Pre-conditions / Requirements:

- Dataflow between ESC and SWW: Reliable data exchange between the ESC members and SWW is crucial.
- Connectivity between EMS and Aurora Software: EMS must seamlessly integrate with Aurora, a system used by SWW, to ensure complete data transmission.

–	Compliance with Data Privacy Regulations: All data handling must comply with GDPR and other relevant data protection laws.

*Success Criteria:*Success is achieved when the billing items generated by the system are consistent with the actual energy production and consumption data within the ESC. This ensures accuracy and legal compliance in the energy sharing and billing processes.

Expected Outcomes: The system will serve as an alternative to costly, licensed ESC management software, allowing SWW and other energy providers to manage ESCs more cost-effectively, while ensuring legal compliance, data privacy, and operational efficiency. This will also enable further scalability for other similar communities in Germany.

Use Case UC_SWW_02: Integration of Flexibility Aggregation and Trading via FIWARE EMS

Overview: This use case involves the integration of the Energy Management System (EMS) with Stadtwerke Wunsiedel's (SWW) Aurora software to facilitate the aggregation and trading of energy flexibilities. By managing flexible energy resources, the system enables dynamic adjustments to energy loads, helping balance supply and demand within the local Energy Sharing Community (ESC). This integration allows the energy provider to optimize grid performance and manage the energy demand more efficiently by leveraging the flexibility available from prosumers and consumers within the ESC.

Objective:

–	Enable the control of flexible energy loads to optimize grid conditions and the energy demands within the ESC.
–	Aggregate flexible energy capacities from community members and trade them on energy markets to enhance economic efficiency and ensure grid stability.
–	Support the ESC in utilizing distributed energy resources for optimized energy use and market participation.

Target Users:

–	Prosumers: Members who can generate and store energy, and provide flexibility to the system.
–	Consumers: Households and businesses with controllable energy loads.
–	Small and Medium Enterprises (SMEs): Businesses that can contribute and benefit from flexibility trading.
–	SWW (Stadtwerke Wunsiedel): The utility responsible for grid management and the operation of the ESC.

*Innovation:*This use case empowers households, consumers, and businesses to actively participate in the energy flexibility market, which was traditionally limited to larger energy producers and industrial players. By utilizing their energy flexibility, prosumers and consumers can contribute to energy balancing and potentially receive financial benefits. This approach fosters more decentralized and participatory energy management in local communities.

Pre-conditions / Requirements:

–	Controllable Assets: Flexibility requires the availability of controllable assets, such as Intelligent Metering Systems (IMS) or CLA-ready (Controllable Load Assets) ImSys.
–	Compatibility between EMS and Aurora: Seamless communication between the EMS and SWW's Aurora software is essential to facilitate real-time flexibility management and trading.

Success Criteria: Success is measured by the ability to effectively trade energy flexibilities within the ESC, ensuring that the aggregated flexibility from community members is optimally utilized to benefit both grid management and market participation.

Expected Outcomes: The integration enables the effective trading of energy flexibilities within the ESC, helping to stabilize the grid, reduce costs, and create new revenue streams for ESC members. By successfully managing and trading flexibilities, this approach will support a more resilient and adaptable energy system, benefiting both the local community and the wider grid network.

Use Case UC_SWW_03: Enhance Flexibility within Energy Sharing Community

Overview: This use case focuses on the integration of a 40 kW DC battery into an existing Energy Sharing Community (ESC) to optimize self-sufficiency and energy management. The battery will be managed via the EMS to enhance energy storage capabilities and allow for better balancing of supply and demand within the community. Additionally, the system may simulate the integration of electric vehicles to further optimize energy use and storage within the ESC.

Objective:

- Integrate a 40 kW battery into the ESC and manage its operation via the EMS.
- Optimize energy self-sufficiency for the ESC by using the battery for energy storage and load balancing.
- Enable simulations of electric vehicles within the ESC to explore additional flexibility and energy efficiency opportunities.

Target Users:

- Brewery: A key member of the ESC that can benefit from enhanced energy management and flexibility.
- Community Members: Prosumers and consumers within the ESC who will benefit from improved energy storage and self-sufficiency.

Innovation: The integration of a large battery system within the ESC represents a significant innovation in terms of energy flexibility and self-sufficiency. By utilizing advanced energy storage solutions and potentially simulating electric vehicle usage, the ESC can increase its ability to balance energy supply and demand dynamically, leading to greater resilience and independence from the external grid.

Pre-conditions / Requirements:

- Connectivity: Reliable communication between the 40 kW battery and the EMS is essential for efficient management and control.
- Infrastructure Readiness: The ESC must be prepared for the physical and technical integration of the battery.

Success Criteria: Success is defined by the successful installation and control of the 40 kW battery via the ESC Management Software/ EMS. The battery must function efficiently within the ESC, contributing to improved energy self-sufficiency and flexibility.

Expected Outcomes: The installation of the battery will enhance the self-sufficiency of the Energy Sharing Community by providing a robust energy storage solution. This will allow the community to store excess energy, reduce reliance on the external grid, and improve the overall stability and efficiency of energy use within the ESC

2.3 Chalmers Campus Energy Community (Chalmers)

The pilot aims to advance the Energy Management System (EMS) from the I-Greta project by incorporating elements such as the Local Energy Market, Local Flexibility Market, and alternative grid tariff designs. The goal is to develop a flexible local energy system and create a roadmap for transforming Chalmers Campus into an Energy Community. This involves reducing consumption, enabling energy exchange, and implementing Vehicle-to-Grid (V2G) mobility infrastructure.

Pilot Description

Background: The EMS from the I-Greta project has demonstrated effectiveness in energy management. The pilot seeks to expand this system to provide flexibility, thereby establishing Chalmers Campus as a self-sustaining Energy Community.

Scope: The pilot will encompass non-residential buildings managed by Akademiska Hus and residential structures such as the HSB Living Lab and the Gibraltar Guesthouse on Chalmers Campus.

Target Energy Community: Chalmers Campus, with its diverse mix of academic, residential, and support structures, aims to become a model for sustainable energy practices.

Energy Consumption and Production: The focus is on optimizing energy use and production, integrating renewable energy sources, and implementing V2G technology.

Technical Framework

Infrastructure and Technologies Used: The pilot will use an upgraded EMS from I-Greta, V2G infrastructure, smart meters, FerroAmp Energy Hub, renewable energy installations, and an advanced system for testing local markets. It will also involve alternative tariff designs and provide flexibility to actors such as the Distribution System Operator (DSO) and Transmission System Operator (TSO).

Integration with Existing Systems: The EMS will interface with existing building management systems, V2G components, and grid connections.

Data Requirements and Sources: The pilot will require data on consumption and production, tariff and market data, vehicle usage patterns, and energy exchange records.

Regulatory and Legal Considerations

Legal Form of EC Pilot: The regulation related to Energy Communities is in the process of transfer from EU law and we will consider the inter-building energy exchange under the coming regulation as the policy sandbox.

Compliance Requirements: The project must comply with Swedish and EU energy regulations, transport laws for V2G, and data protection standards.

Potential Legal and Regulatory Challenges: There may be a need to develop a regulatory sandbox for alternative grid tariffs, local markets, cross-building energy trading, and V2G implementation.

Community Engagement

Stakeholder Identification: Key stakeholders include university administration, Akademiska Hus, energy providers, local authorities, transport sector stakeholders, and campus residents.

Engagement Activities: The project will feature interactive workshops, EMS monitoring apps for stakeholders, public consultations for the roadmap, and educational campaigns about V2G and energy savings.

Community Feedback Mechanisms: To be announced (TBA).

Use Cases for Demo Pilots

Use case ID: UC_CHA_01 **Energy Management for Academic Buildings**:

Objective: Optimize energy consumption and production in academic buildings.

*Target Users***:** Building owners, tenants, students, academic staff.

*Innovation***:** Implementation of an advanced EMS with flexibility provision.

Success Criteria: Reduction in overall energy consumption, increased use of renewable energy, and demonstrated cost savings on energy bills.

Use case ID: UC_CHA_02 **Local Energy Market and Flexibility Trading**:

Objective: Establish a local energy market for flexibility trading within the Chalmers Campus.

Target Users: University administration, energy providers.

Innovation: Creation of a local energy market platform and implementation of flexibility trading mechanisms.

Success Criteria: Improved energy efficiency and optimized energy consumption across the campus, leading to reduced energy costs.

Use case ID: UC_CHA_03 **Integration of Vehicle-to-Grid (V2G) Technology**:

Objective: To enable seamless integration of Vehicle-to-Grid (V2G) technology into the energy ecosystem, allowing electric vehicles (EVs) to function as dynamic energy storage units. This will optimize grid stability, enhance renewable energy utilization, and provide financial incentives for EV owners through bidirectional energy flow.

Target Users:

- EV owners who want to optimize energy use and benefit financially from contributing to grid stability.
- Grid operators seeking efficient demand response solutions.
- Charging station operators for deploying V2G-compatible infrastructure.
- Renewable energy producers needing storage solutions to handle supply variability.
- Energy service providers aiming to improve service reliability and customer engagement.

Innovation:

- Bidirectional Energy Flow
- Smart Energy Management
- Dynamic Pricing Mechanisms

Success Criteria

- *Reliable and seamless integration of V2G systems with existing grid infrastructure.*
- *High system uptime and robust data security measures.*
- *Positive user feedback on ease of use and financial benefits.*
- *Reduction in energy costs for grid operators and EV owners.*
- *Increased revenue streams for energy service providers through efficient energy trading.*
- *Improved grid stability and reduction in blackouts or overload incidents.*
- *Enhanced capability to manage peak demand periods effectively.*

2.4 Jättesten Energy Community - (Chalmers)

The Jättesten Energy Community in Göteborg represents a pioneering initiative aimed at transforming a residential sector comprising 24 buildings and an publich schol and pre-school into a highly efficient and partly self-sustaining energy community. This pilot project seeks to advance current energy management practices through the integration of photovoltaic (PV) systems, battery energy storage systems (BESS), and an advanced Energy Management System (EMS). The project's central focus is on optimizing energy production, consumption, and storage, while enabling inter-building energy exchange to maximize efficiency and sustainability across the community.

Pilot description

The pilot encompasses the entire Jättesten neighbourhood, incorporating both residential buildings and a school. The project's primary objective is to optimize solar energy utilization through PV systems, coupled with the intelligent storage of surplus energy via BESS. The EMS will facilitate real-time monitoring and management of energy flows, ensuring that energy is optimally consumed or redistributed within the community according to dynamic demand profiles, thereby minimizing grid dependency and enhancing local energy resilience.

The Jättesten neighbourhood is envisioned as a model for sustainable urban living, characterized by optimized local energy production and consumption, and the facilitation of inter-building energy exchanges. This framework is designed to achieve high levels of energy self-sufficiency and operational efficiency within the community.

The project emphasizes the optimal sizing and deployment of PV systems to maximize solar energy production during peak sunlight hours. This energy will be stored in BESS and dynamically allocated among buildings based on their real-time energy demand profiles. The EMS will continuously adjust energy flows to ensure that consumption is closely aligned with production, thereby minimizing waste and reducing reliance on external energy sources.

Figure 2. 3D model of Jättesten neighbourhood

Technical Framework

Infrastructure and Technologies Used:

The pilot project will deploy advanced PV systems, BESS, and a sophisticated EMS to manage the community's energy production, storage, and consumption. The EMS will play a critical role in modelling power profiles across the buildings and optimizing the inter-building exchange of energy. This approach is intended to ensure that energy is used where it is most needed, enhancing overall community efficiency and reducing energy losses.

Integration with Existing Systems:

The EMS will be developed and integrated, providing seamless control over energy optimization processes across the neighbourhood. By continuously modelling and updating power profiles for each building, the EMS will optimize energy distribution, ensuring that excess energy is efficiently stored or transferred to other buildings with higher demand.

Data Requirements and Sources:

The pilot will require detailed data on energy production from PV systems, BESS capacity and utilization, as well as consumption patterns across the participating buildings. This data will be instrumental in developing and refining power profiles, which the EMS will use to optimize energy distribution and storage.

Regulatory and Legal Considerations

Legal Form of EC Pilot:

The Jättesten Energy Community is a collaborative endeavour involving local authorities, energy providers, and the residents of the Jättesten neighbourhood.

Compliance Requirements:

The project must adhere to both local and national energy regulations, particularly those governing renewable energy production, storage, and inter-building energy exchanges. Furthermore, the project must ensure compliance with data protection standards relevant to the collection and management of energy consumption data.

Potential Legal and Regulatory Challenges:

Challenges may include navigating the regulatory landscape surrounding energy storage, grid interaction, and inter-building energy trading. The project may necessitate the development of new regulatory frameworks to accommodate the innovative energy management practices being implemented.

Community Engagement

Stakeholder Identification:

Key stakeholders in the project include local government authorities, energy providers, the school administration, and residents of the Jättesten neighbourhood.

Engagement Activities:

The project will involve a series of workshops, community meetings, and the deployment of an EMS monitoring application, which will allow residents to track energy usage and savings in real time. Additionally, there will be educational initiatives aimed at promoting the benefits of renewable energy, efficient energy management, and community-based energy exchanges.

Community Feedback Mechanisms:

Feedback mechanisms will include structured surveys, focus group discussions, and direct input through the EMS application, facilitating continuous refinement of energy management strategies and ensuring alignment with community needs and preferences.

Use Cases for Demonstration Pilots

Use Case ID: UC_JÄT_01 - Energy Management for Residential Buildings:

Objective: To optimize energy consumption and production within the residential buildings of the Jättesten neighborhood.

Target Users: Residents, building managers.

Innovation: Implementation of an advanced EMS integrated with PV and potential BESS to manage energy flows efficiently.

Success Criteria: Reduction in overall energy consumption, increased reliance on renewable energy, and demonstrated cost savings on energy expenditures.

Use Case ID: UC_JÄT_02 - Optimal Solar Energy Production and Storage:

Objective: To maximize solar energy production and ensure its efficient storage for later use, thereby maintaining energy availability during peak demand periods.

Target Users: Energy providers, community managers.

Innovation: Deployment of PV systems and intelligent BESS to optimize the capture, storage, and distribution of solar energy.

Success Criteria: Increased solar energy production, effective energy storage, and reduced dependence on external energy sources.

Use Case ID: UC_JÄT_03 - Inter-Building Energy Exchange:

Objective: To enable energy exchange between buildings, optimizing energy use across the community by matching power profiles and aligning consumption with available production.

Target Users: The entire Jättesten community.

Innovation: Application of an advanced EMS to model and manage energy flows between buildings, ensuring that energy is distributed where it is most needed.

Success Criteria: Enhanced energy efficiency, minimized energy wastage, and increased community resilience.

2.5 FDD and Optimization of Energy Community (TUW / DiLT)

Pilot Description

TU Wien/DiLT leverages its extensive experience in fault detection and diagnosis (FDD) and optimization for energy systems. Existing monitoring platforms, such as INFRAMONITOR and Cool Quarter Plus, provide the foundational data for developing advanced energy community management solutions. The pilot aims to enhance the operation of local energy communities by incorporating physics-informed AI, greenhouse systems, and data-driven optimization techniques. The project focuses on energy-efficient operation of photovoltaic (PV) systems, batteries, and pumps, with an emphasis on fault detection and diagnosis at the production level.

Scope:

The pilot covers diverse infrastructure, including laboratories, offices, single-family houses, and commercial buildings in the Inffeldgasse area. It examines energy consumption and production across these setups, analyzing potential improvements in system diagnostics and integration with greenhouse energy communities.

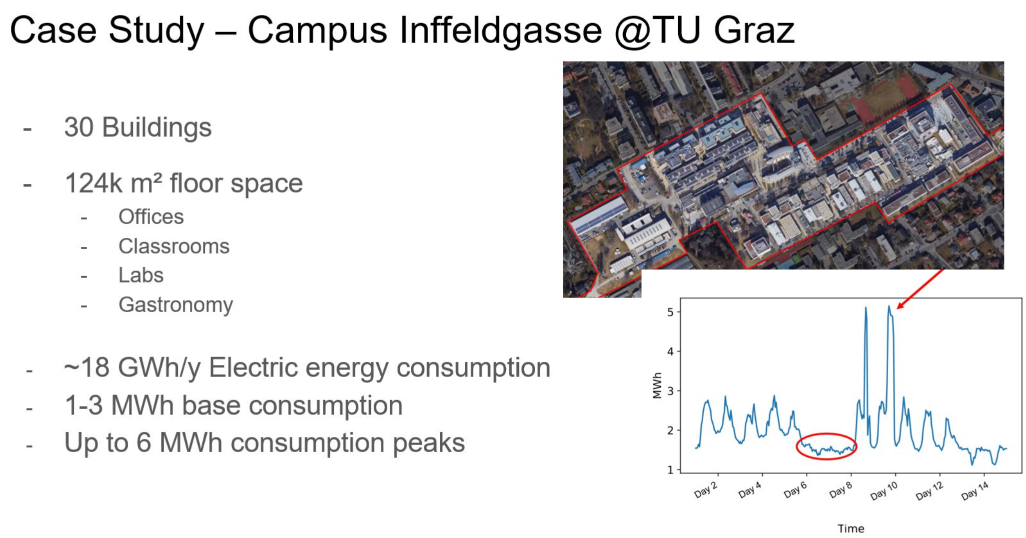

Figure 3. Overview key facts of pilot side Campus Inffeldgasse

Target Energy Community

Inffeldgasse neighborhood, with an optional reference to district-level energy communities.

Technical Framework

Infrastructure and Technologies Used:

- Monitoring and diagnostic tools like INFRAMONITOR and Cool Quarter Plus.
- Physics-informed AI for energy data analysis.
- Communication and control frameworks (MQTT, Docker).
- Standalone packages for data privacy and security, with sandboxed API interfacing.

Integration with Existing Systems:

The pilot focuses on developing interoperable systems that integrate seamlessly with existing monitoring infrastructure. Key objectives include data security, privacy compliance, and modular system development.

Data Requirements and Sources:

Comprehensive data collection at the production level, including PV systems, battery storage, and energy consumption points

Regulatory and Legal Considerations

Legal Form of EC Pilot: The current energy community lacks formalized structures, requiring regulatory and legal alignment. The pilot focuses on creating viable frameworks.

Compliance Requirements: The pilot adheres to Austrian and EU regulations, emphasizing data compliance, privacy, and secure processing.

Potential Challenges: Addressing issues related to data usage, processing, and storage within the legal frameworks.

Community Engagement

Stakeholder Identification: The pilot engages key stakeholders such as labs, offices, campus facilities, and local households.

Engagement Activities: The project will feature educational campaigns, interactive sessions, and workshops aimed at increasing awareness and participation in energy community initiatives.

Community Feedback Mechanisms: Surveys and internal system feedback channels will be implemented to gather insights and improve community engagement.

Use case ID: UC_INF_01: Fault detection and diagnosis for energy systems

Objective: To lower energy usage, enhance occupant comfort, and ultimately decrease maintenance and operational costs.

Target users: Building owners, operators, engineers, maintainers.

Innovation: Flagging of anomalies based on conditional probabilities; automated fault detection and root cause analysis without relying on faulty priors.

Pre-condition / Requirements: High-resolution measurements for both general and special loads, routines of special loads, possible the non-operational variables such weather conditions, etc.

Success criteria: Faulty operation is correctly identified as anomalous and diagnosed.

Use case ID: UC_INF_02: General and special load analysis for energy communities

Objective: To model short- and long-term energy consumption pattern with and without knowing special loads (e.g. laboratories with really high energy consumption).

Target users: Building owners, operators, engineers, maintainers.

Innovation: Categorization and impact analysis of special loads separately from general energy usage.

Pre-condition / Requirements: High-resolution measurements for both general and special loads, routines of special loads, possible the non-operational variables such weather conditions, etc.

Success criteria: Prediction accuracy.

2.6 Energy Community Niedergrail (TU Wien / DiLT / dwh)

The EC Niedergrail aims to demonstrate an efficient and sustainable energy-sharing model among community members. This initiative focuses on leveraging photovoltaic systems and energy storage solutions to optimize individual consumption patterns, improve energy efficiency, and increase energy independence within the community.

Pilot Description

The energy community combines photovoltaic generation with behind-the-meter energy storage systems to align energy production with consumption. The project focuses on optimizing charging and discharging patterns through advanced control algorithms, transitioning from a semi-automatic to a predictive and automated energy management system.

The EC consists of six households, including small family homes and farm buildings in southern Styria. All participants are connected within the same transformer station on grid levels 6 and 7. The project investigates how storage systems can enhance the efficiency of locally produced solar energy.

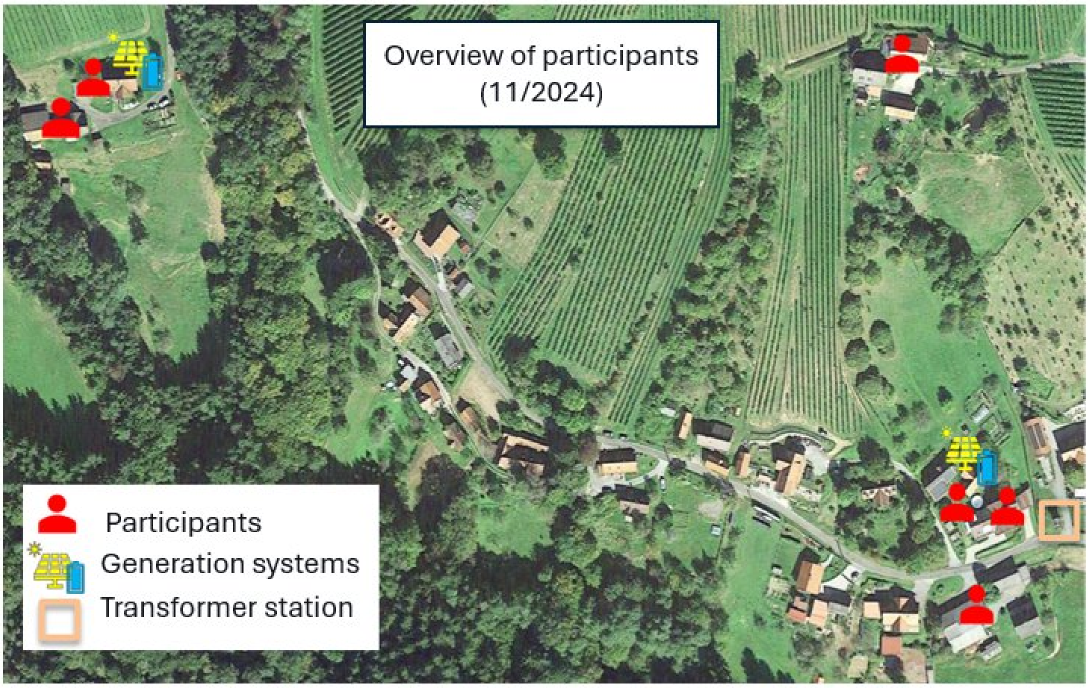

Figure 4. Overview energy community Niedergrail

Target Energy Community:

The participants are households located in southern Styria, sharing resources under a local energy community framework.

Energy Consumption and Production:

Electricity Consumption: ~7.8 MWh/year

PV Generation: ~11.6 MWh/year

Energy Storage Systems: Two systems totaling ~28 kWh.

Reference Energy Community: None specified.

Technical Framework

Infrastructure and Technologies Used:

- Each household is equipped with Raspberry SmartPi 3.0 monitoring devices for real-time voltage and current measurement.
- Fronius inverters integrate PV and battery systems, providing insights into electricity generation and state of charge (SOC).
- Data is stored in an InfluxDB and visualized through Grafana.

Integration with Existing Systems:

- The monitoring and control systems are fully integrated with the participants' existing electrical infrastructure, ensuring seamless data collection and system operation.

Data Requirements and Sources:

- Real-time data on energy consumption and generation.
- Charging and discharging behaviours from storage systems, derived from smart meters and device logs.

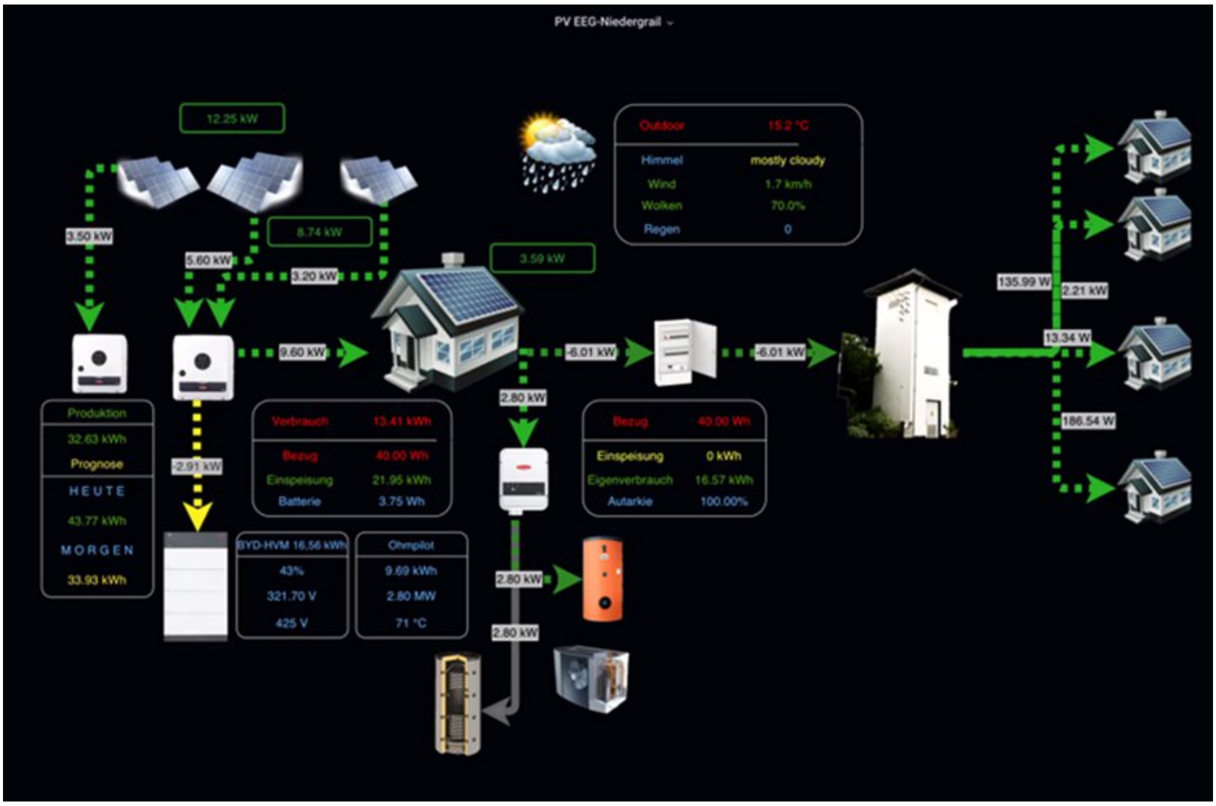

Figure 5. Online dashboard of the energy flows in the community

Regulatory and Legal Considerations

Legal Form of EC Pilot:

The EC is formally established as an association (founded in October 2022).

Compliance Requirements:

The pilot adheres to Austrian laws for local energy communities.

Potential Legal and Regulatory Challenges:

The absence of regulations governing the verification of locally generated electricity (vs. grid electricity) presents challenges for integrating battery storage systems into the EC framework.

Community Engagement

Stakeholder Identification:

Key stakeholders include the current six households participating in the EC, with potential expansion to additional households within the same transformer supply area.

Engagement Activities:

Informational campaigns and word-of-mouth recommendations encourage broader participation and awareness.

Community Feedback Mechanisms:

Structured questionnaires and feedback systems ensure continuous stakeholder involvement and satisfaction.

Use case ID: UC_EC_01: Demand side management for prosumers with flexible loads

Objective: To effectively manage and optimize the prosumer's energy demand while reducing energy waste and dependence on the grid operator.

Target users: Building owners, operators, engineers, maintainers.

Innovation: Advanced algorithms and techniques to monitor and control prosumer energy consumption in real-time.

Pre-condition / Requirements: High-resolution measurements (15-Min-Measurements), participants routines (if possible), non-operational variables, number of devices etc.

Success criteria: Feedback from prosumer regarding financial and/or operational benefits.

Use case ID: UC_EC_02: Demand Side Management for energy communities

Objective: To effectively manage and optimize the community’s energy demand while reducing prosumer’s energy waste and minimizing reliance on the grid operator.

Target users: Building owners, operators, engineers, maintainers.

Innovation: AI-powered algorithms that dynamically adjust energy demand by controlling flexible loads based on renewable energy availability and grid conditions.

Pre-condition / Requirements: High-resolution measurements (15-Min-Measurements), participants routines (if possible), non-operational variables, number of devices etc.

Success criteria: Feedback from the community, quantitative metrics and qualitative analysis.

Use case ID: UC_EC_03: Demand side management for prosumers with flexible pricing

Objective: To efficiently manage and optimize the prosumer's energy demand while reducing reliance on the grid operator, and leveraging optimization (AI and RL) techniques to handle surplus energy through sales to consumers and the grid operator.

Target users: Building owners, operators, engineers, maintainers.

Innovation: Real time pricing strategy that adjust energy sale prices based on supply-demand conditions and market dynamics.

Pre-condition / Requirements: High-resolution measurements (15-Min-Measurements), participants routines (if possible), non-operational variables, number of devices etc.

Success criteria: Feedback from prosumer regarding financial and/or operational benefits.

2.7 Energy Community Mariatrost (TU Wien / DiLT / dwh)

The EC Mariatrost aims to demonstrate an efficient and sustainable energy-sharing model among community members. This initiative focuses on leveraging photovoltaic systems and energy storage solutions to optimize individual consumption patterns, improve energy efficiency, and increase energy independence within the community.

Pilot Description

The EC consists of 19 participants with 5 PV systems (approx. 52 kWp in total).

Established as a formal association in July 2022 and fully organized by March 2023, the EEG Mariatrost includes diverse members such as private individuals, small businesses, and public institutions. It aims to expand by adding more PV installations, an electric vehicle charging station, and potentially an e-car sharing service, while fostering partnerships in the community through a grassroots approach.

Target Energy Community:

The participants are households and small businesses, located in Styria in Graz, sharing resources under a "regional" energy community framework.

Energy Consumption and Production:

Electricity Consumption from grid: ~36 MWh/year

PV Generation: ~53MWh/year

Energy Storage Systems: none

Reference Energy Community: None specified.

Technical Framework

Infrastructure and Technologies Used:

- Each household is equipped with a smart meter device from the grid operator.
- 5 PV systems are installed in the community.

Integration with Existing Systems:

- The monitoring systems are fully integrated with the participants' existing electrical infrastructure, ensuring seamless data collection and system operation.

Data Requirements and Sources:

- Real-time data on energy consumption derived from smart meters.

Regulatory and Legal Considerations

Legal Form of EC Pilot:

The EC is formally established as an association (founded in March 2023).

Compliance Requirements:

The pilot adheres to Austrian laws for regional energy communities.

Potential Legal and Regulatory Challenges:

The absence of regulations governing the verification of locally generated electricity (vs. grid electricity) presents challenges for integrating battery storage systems into the EC framework.

Community Engagement

Stakeholder Identification:

Key stakeholders include the current households participating in the EC, with potential expansion to additional households within the same transformer supply area in the urban area.

Engagement Activities:

Informational campaigns and word-of-mouth recommendations encourage broader participation and awareness. The local politicians of the district Mariatrost are updated periodically about the progress and expansion possibilities.

Community Feedback Mechanisms:

Structured questionnaires and feedback systems ensure continuous stakeholder involvement and satisfaction.

Use case ID: UC_EC_04: Electricity consumption forecasting

Objective: To model energy profiles using classical and advanced AI/ML techniques and derive forecasts to better understand community energy demands.

Target users: Building owners, operators, engineers, maintainers.

Innovation: Forecasting energy demand to proactively manage and balance community energy loads, reducing strain on the grid.

Pre-condition / Requirements: High-resolution measurements (15-Min-Measurements), participants routines (if possible), non-operational variables.

Success criteria: Evaluation metrics for prediction analysis, such errors and residual analysis.

Use case ID: UC_EC_05: Electricity consumption disagreggation

Objective: To disaggregate the community's total energy consumption into its individual household components.

Target users: Building owners, operators, engineers, maintainers.

Innovation: Enabling demand response strategies at the household level based on disaggregated load data, improving overall energy management.

Pre-condition / Requirements: High-resolution measurements (15-Min-Measurements), participants routines (if possible), non-operational variables.

Success criteria: Evaluation metrics for prediction analysis, such errors and residual analysis

2.8 FH JOANNEUM & FH CAMPUS 02

This pilot aims to extend the I-Greta setup to reach a higher TRL, by incorporating flexibility markets and increasing the use of hardware-in-the-loop test benches in optimizations.

Furthermore, for selected building energy systems (BES), a monitoring resolution of 1 reading/second is planned. The high resolution monitoring allows further demonstrations for anomaly detection in BES.

- Demo 1: Energy storge participation in flexibility market
- Demo 2: Flexible hot water preparation for office and residential buildings
- Demo 3: Flexible room temperature control

Pilot Description

Background: Demo 1 investigate the ability of typical decentralized energy storages to participate in flexibility energy markets within an energy community.

The different user needs for residential/-nonresidential are included.

Demo 2 investigates smart controlling systems for hot water preparation including power controllers and forecasting models.

To optimize room climate and energy consumption demo 3 focus on intelligent room clima control based on forecasting models within the flexible energy markets and energy community. Feedback loops of users are implemented in the controlling algorithms.

Scope: The demos include a real photovoltaic and energy storage systeme as well as a real building and different heating and cooling systems, all located at the FH CAMPUS 02 and FH Joanneum. Posss-ible time frame for analysis ~ 2 week.

Technical Framework

Infrastructure and Technologies Used: Demo 1 and 3 will be using FIWARE for external communic-ation. The internal communication will be based on different communication technologies like MQTT, Modbus TCP and Bluethooth Low Energy.

Integration with Existing Systems: No real community is investigated

Data Requirements and Sources: The demos are monitored and data is utilized FH CAMPUS 02 and FH Joanneum internally to analyze the demo results. Certain anonymous data sets can be shared with the partners.

Regulatory and Legal Considerations

There is no real energy community (EC) in this pilot, therefore EC-specific legal forms, requirements, and challenges do not apply.

Community Engagement

There are no engagement activities outside the project consortium planned.

Use Cases for Demo Pilots

Use case ID: UC_EAS_01 Energy Management for decentralized laboratories

Overview: Investigation of smart energy management systems for the EAS-Labs in Graz and Kapfen-berg

Objective: Enabling energy sharing between buildings to enhance efficiency across the community by matching power demand with supply and aligning consumption to available generation.

Target users: EAS-Labs of FH Joanneum and FH CAMPUS 02

Pre-condition / Requirements: High-resolution measurements and communication

Success criteria: Distributed control system

Expected outcomes: Improved energy efficiency and cost savings.

Use case ID: UC_EAS_02 Smart Hot Water Preparation

Overview: Investigate methods for smart forecasting hot water preparation

Objective: Based on forecasting models and specific user behaviours control algorithms for hot water preparation are developed.

Target users: Prosumer, consumer

Innovation: Enable residential/-non-residential building to prepare their hot water based on user behaviour and energy markets

Pre-condition / Requirements: Labratory infrastructure

Success criteria: Controller for hot water preparation based on forecasting user behaviour and energy market.

Expected outcomes: Prototype of in intelligent hot water preparation system

Use case ID: UC_EAS_03 Intelligent room climate control

Overview: Investigating smart controllers for room climate

Objective: Optimize the room climate of the laboratory at FH CAMPUS 02 by integrating a forecasting based algorithm and controlling system for the heating and cooling system

Target users: Students and employees of FH CAMPUS 02

Innovation: Intelligent room climate control based on forecasts and user feedback

Pre-condition / Requirements: Interfaces for heating and cooling systems

Success criteria: Smart controllers are integrated within the laboratory

Expected outcomes: Energy cost savings and increasing the self-consumption rate

2.9 GreenMogo Energy Community (UPB)

GreenMogo is a zero-energy building operating in different scenarios to teach various target groups about more sustainable ways of living and building. Within the project, the premise acts as a regulatory restricted prosumer (following the operation of a UniRCon) providing insights on energy needs for modern local energy communities.

Pilot Description

The general grid topology of the GreenMogo trial consists of a family residential building and a conference center (with regular home appliances) with PV generation and BESS interfaced with a Victron inverter and a heat pump for thermal energy transfer. The measurement layer consists of high-reporting rate information (1 frame/second), which is provided by energy meters operating using the Unbundled Smart Meter (USM) concept for energy use, and also provided by the Color Control GX TCP/IP integrated with the Victron Inverter for energy generation (PV and BESS).

Technical Framework

A. Measurement Layer for the load.

The information for the load side integrated in the FIWARE platform is derived from local measurements using the concept of the Unbundled Smart Meter (USM) set on 1 rame/second reporting rate. The classic architecture for the USM is in place consisting of the Smart Metrology Meter (SMM) part (metrology-compliant) and the Smart Meter eX-tension (SMX) implemented using a low-cost processing unit. The GreenMogo UniRCon smart metering infrastructure streaming information for the FIWARE platform consists of three-phase meters installed on the premises. SOCOMEC three-phase meters [15], representing the metrology part of the USM, are used to monitor the energy transfer in the UniRCon environment, having a metering accuracy Class 1 for active energy and Class 2 for reactive energy. The SMX part, based on Raspberry PI (RPI) 3 board [16] (acting as a single board computer) is physically connected to SOCOMEC meter allowing the extraction of high-time resolution instrumentation values (1s resolution). To achieve the high-reporting rate of 1 frame/second, the connection between the SMM and SMX is based on a serial interface (RS485), using the IEC 62056 (DLMS/COSEM) communication protocol [17], 9600 baud communication speed and additionally, for data extraction, specific configuration actions were required. One of the SOCOMEC meters is monitoring a residential power profile (consisting of standard home appliances) and another meter is installed as to observe the energy transfer of a threephase heat pump (with nominal power 3 kW).

B. Measurement Layer for Generation

The UniRCon environment is supplemented with PV panels generation, with 5.5 kW installed power and a local MPPT device to continuously maximize the output power of the PV panels. The flexibility in operation is provided by an energy storage system based on 3 lithium iron phosphate batteries with a built-in battery management system (BMS) summing up to 10.5 kWh. All generation equipment are integrated in a 5 kW Victron Quattro Inverter with Color Control GX (CCGX) control unit of the renewable generation. High-time resolution measurement information (1s resolution) is achieved by connecting a Raspberry PI (RPI) via TCP/IP protocol to the CCGX and performing dedicated software configuration based on Python with additional software calibration. For the acquisition of high reporting rate data from the local RES installation, additional software is needed since the manufacturers' software usually does not supply such high reporting rate data. On the Raspberry Pi, a Python script is running to collect the data locally in .csv files and forward the readings to the FIWARE platform. Generation information is available with a high-reporting rate of 1 frame/second creating the premises for heterogeneous data integration from multiple sources within the powered-by-FIWARE platform under development. A Python script receives a reading roughly every 500 ms and averages over a second before storing and forwarding the data. The storing is done locally in a CSV file including the timestamp and basic load and generation parameters provided by the CCGX. After storing the data, the same data point is forwarded to the FIWARE platform and can be used either for visualization or other third-party applications integration.

C. Information integration framework

The core of the trial site software implementation is the open-source FIWARE framework, showcasing with its integration layers. In the initial stage of implementation, the "*Data Harvesting Layer*" plays a pivotal role. This layer facilitates the seamless integration of the various types of measurement information sources. The primary objective of the FIWARE framework is to unify the format of data exchange and the storage of energy measurement information gathered from various sources. Within the *Temporary Logic Layer*, the SMX Converter and GX Converter, lightweight and configurable NodeJs applications, are the key components within this level. They can run on various machines and operating systems, continuously processing real-time changes in logs or manually triggered to review existing logs. They ensure consistent formatting of output sent to the FIWARE Orion Context Broker by interpreting different types of logs and allow for independent querying of data saved by each instance, along with the flexibility to direct calls to specific IPs or hosts as required for networking infrastructure. As part of the Persistent Logical Layer, the unified platform's foundation revolves around context data, describing component identity, attributes, and type. The FIWARE NGSI protocol serves as a flexible means to exchange various data types with the platform, enabling context information management. The Orion Context Broker, at the core of any FIWARE-based framework, receives and manages context information in NGSI format, allowing for processing, analysis, and integration with other layers. For the Data Storage Layer, the Orion Context Broker receives context information, which is then stored in a MongoDB database for long-term storage. MongoDB offers advantages such as flexible operation, native aggregation, scalability, and JSON compatibility. This integration allows for the inclusion of data from various devices with different structures and communication protocols, enhancing the overall flexibility of the framework. The NGSI format for the Orion Context Broker provides a distinct representation of the data found in MongoDB. For the load side, when integrating smart energy meters with Orion, each meter will be distinguished by its name and accuracy class containing as values the associated instrumentation values as depicted in [22]. What concerns the Presentation Layer, the final component of the framework focuses on integrating third-party applications, with an initial example being a visualization and pre-processing tool for load and generation measurement information. Notably, this tool incorporates high-reporting rate measurements (1 frame/second) from various sources (smart meters and CCGX) using FIWARE technology. A demo version of the platform serves as an introductory application, showcasing ongoing research and experiments in achieving optimal intelligent and versatile solutions for integrating measurement information from multiple sources and facilitating flexible data exchange.

D. Visualisation architecture

The open-source platform's versatility is given by the integration of multiple sources of information (load and generation) with high-reporting rate (1 frame/s). A first step as a third-party application integration is the presentation layer implemented as visualization and preprocessing application in association with Grafana.

Regulatory and Legal Considerations

To address technical and financial barriers, as well as policy ambiguities in the energy sector, a new regulatory concept called Unidirectional Resilient Consumer (UniRCon) is analyzed with multiple advantages for optimal operation and scheduling within an Energy Management System (EMS) in different architectures and scenarios. [6], [7]. UniRCon offers a resilient framework that enables the grid to accommodate traditional "load-only" customers without requiring modifications for the public grid to handle power injection and ensure grid stability. The regulatory constraints in GreenMogo is about load-only operation, with no injection of power into the public grid.

Community Engagement

The project will involve a series of workshops, community meetings, and the deployment of an EMS monitoring application, third party application integration, data analytics, which will allow residents to better engange in energy initiatives. Additionally, there will be educational initiatives aimed at promoting the benefits of renewable energy, efficient energy management, and community-based energy exchanges.

Use Cases for Demonstration Pilots

UC_RO_01 = Optimal operation of Prosumers with flexibilities (generation, storage, loads)

- Scenario = Pure load operation (no power Injection in the grid)

Overview: Within this use-case, the goal is for demonstration and quantification of flexibility of generation and consumption at prosumer level. The Prosumer (PV + el. Storage

+ flexible load profile) operates in an optimal way according to the scenario of no-power injection in the main LV grid by modulating P1 and meeting grid-connection conditions. The optimal operation is developed using one year historical measurements with high resolution (1s) for Pload and for Pgen, power flow models developed in Typhoon HIL, context information (weather, teaching schedule, events) and inverter in various configurations.

Target users: Prosumers, Clusters of prosumers, Building owners, operators, engineers, maintainers

Innovation: Optimal operation of a microgrid with regulatory constraints.

Pre-condition / Requirements: High-resolution measurements

Success criteria: Follow the pre-defined power profile agreed with the DSO.

Expected outcomes: Pre-defined power profiles with the DSO, energy exchange between prosumers.

UC_RO_02 = Optimal operation of Prosumers within an energy community

- Scenario = Pure load operation (no power Injection in the grid)

Overview: This UC will demonstrate and quantify exchange of energy at community level by using hybrid connections.Two prosumers (PV + el. Storage + flexible load curve + restriction Pmax on grid connection) exchange energy through an internal (private) link according to several scenarios, when there is excess at P1 premises and it is a need at P2.

Target users: Prosumers, Clusters of prosumers, Building owners, operators, engineers, maintainers

Innovation: Flexibility exchange among prosumers and regulatory constrants

Pre-condition / Requirements: High-resolution measurements

Success criteria: Energy exchange to meet the regulatory constraints.

Expected outcomes: Pre-defined power profiles with the DSO, energy exchange between prosumers..

UC_RO_03 = Data Analytics and Anomaly detection

Overview: By combining anomaly detection with automated machine learning, in the context of power systems measurements, the use case aims to improve the data analytics approach for such data and contribute to the real-time operation and control of local microgrids (energy communities). This use case will investigate a data analytics application based on high reporting rate power measurements. Outlier detection to label anomalies in the time series can be combined with automated machine learning libraries for efficient forecasting and dimensionality reduction. In the project the method will be investigated for establishing an empirical relation between the occurence rate of outliers in the measurement time series and the forecasting performance. Results provide a discussion on the best, domain-adaptive, parametrisation and modelling options which are highly suited for power system measurements using open source software libraries.

Target users: Building owners, operators, engineers, maintainers

Innovation: Flagging of anomalies based on conditional probabilities

Pre-condition / Requirements: High-resolution measurements

Success criteria: Faulty operation is correctly identified as anomalous

Expected outcomes: Early anomaly detection leading to early system repair or mitigation strategies. Eventually leading to improved energy efficiency and cost savings.

3. Overall KPIs

Key Performance Indicators (KPIs) provide a structured framework for measuring the success and effectiveness of the ECom4Future initiative across its diverse pilot sites. The following categories outline the primary KPIs and their associated objectives and targets:

Energy Efficiency Improvement: This KPI assesses the overall reduction in energy consumption across participating buildings and communities. The target is a 10–20% reduction, achieved through advanced energy management systems, optimized energy flows, and user engagement strategies. Success is measured by monitoring energy consumption patterns before and after implementing project interventions.

Renewable Energy Utilization: This metric evaluates the contribution of renewable energy sources, such as photovoltaic (PV) systems, to the total energy demand. The goal is for renewables to supply at least 30–50% of the energy used across the trial sites. High-resolution data from PV systems and other renewable sources will track progress toward this target.

Flexibility and Demand Response: The effectiveness of flexibility mechanisms is measured by the amount of energy flexibility offered and utilized within local markets. The target is to utilize 70–90% of available flexibility, ensuring optimized grid performance and efficient energy usage. This includes demand-response measures and market-based trading of energy flexibility.

Energy Storage Efficiency: This KPI determines the performance and reliability of Battery Energy Storage Systems (BESS). The goal is to achieve 80–90% storage efficiency, maximizing the utility of stored energy while minimizing losses. Metrics include energy conversion rates and cycle efficiency of the installed systems.

Anomaly Detection and System Reliability: This KPI tracks the performance of real-time anomaly detection systems to ensure energy systems' reliability and operational safety. The target is to detect and resolve 95–100% of anomalies within predefined timeframes. Early fault detection will prevent energy losses and optimize maintenance schedules.

Community Engagement and Satisfaction: Stakeholder involvement and satisfaction are central to the initiative's success. This KPI measures community engagement rates and overall satisfaction, with a target of 80–90% satisfaction levels. Engagement activities, such as workshops, surveys, and feedback mechanisms, ensure that solutions align with community needs and expectations.

Cost Savings and Economic Viability: This KPI evaluates the economic benefits of energy management solutions for community members, aiming for a 15–25% reduction in energy costs. The cost-effectiveness of technologies and operational models will be assessed, highlighting the financial advantages of adopting sustainable practices.

Regulatory Compliance and Legal Considerations: The initiative must operate within the legal frameworks of each participating region. This KPI tracks the resolution of regulatory issues, with a target of 100% compliance and no significant legal challenges. The project also aims to explore policy sandboxes to test innovative regulatory frameworks.

Scalability and Replicability: To ensure the broader impact of the project, this KPI identifies scalable and replicable elements within the pilot sites. The target is to define at least 2–3 elements that can be adapted and applied to other contexts, supporting the growth of sustainable energy communities across Europe.

Data Management and Security: Ensuring the security and integrity of data is critical to the initiative. This KPI monitors the occurrence of data breaches or security issues, with a goal of zero breaches and full compliance with data protection regulations. The implementation of robust data management practices is vital to maintaining stakeholder trust and system reliability.

The defined KPIs establish clear objectives and measurable targets for the ECom4Future initiative, ensuring a balanced approach to innovation, sustainability, and community impact. By monitoring these indicators, the project can adapt and refine its strategies, contributing to the successful development of energy communities that are efficient, reliable, and socially inclusive. The summary of KPIs to evaluate the pilots are summarised in Table 2.

Table 2. KPIs to evaluate the pilots

KPI Category	KPI	Objective	Target
Energy Efficiency Improvement	Percentage reduction in overall energy consumption	Assess the improvement in energy efficiency across buildings and communities.	Achieve a 10-20% reduction in energy consumption.
Renewable Energy Utilization	Percentage of energy demand met by renewable sources	Measure the contribution of renewable energy to the overall energy consumption.	At least 30-50% of energy demand met by renewable sources.
Flexibility and Demand Response	Amount of flexibility offered and utilized (kW/%)	Evaluate the effectiveness of flexibility mechanisms.	70-90% of available flexibility utilized in local markets.
Energy Storage Efficiency	Efficiency of energy storage systems	Determine the performance of Battery Energy Storage Systems (BESS).	Achieve 80-90% storage efficiency.
Anomaly Detection and System Reliability	Number of anomalies detected and resolved in real-time	Track the performance of anomaly detection systems.	95-100% of detected anomalies addressed within a defined time frame.
Community Engagement and Satisfaction	Stakeholder engagement rate and satisfaction level	Measure the involvement and satisfaction of community members.	Achieve 80-90% satisfaction rate.
Cost Savings and Economic Viability	Reduction in energy costs for community members	Assess the economic benefits of the energy community.	Achieve a 15-25% reduction in energy bills.
Regulatory Compliance and Legal Considerations	Number of compliance issues encountered and resolved	Ensure all pilots operate within legal frameworks.	100% compliance with no major regulatory issues.
Scalability and Replicability	Number of elements scalable or replicable	Evaluate the potential to scale or replicate the pilot projects.	Identify 2-3 scalable or replicable elements.
Data Management and Security	Number of data breaches or security issues reported	Monitor the effectiveness of data management practices.	Zero data breaches with full compliance.

4. Timeline

The timeline for WP6 encompasses the critical phases of trial site planning, setup, and operation, beginning in early 2024 and continuing through 2025. Initial activities focus on establishing infrastructure and aligning technical frameworks (T6.1) to support subsequent tasks. Monitoring of energy consumption and production (T6.2) will follow, running in parallel with the integration of market schema and user feedback analysis (T6.3) to ensure seamless functionality. Full-scale trial operations (T6.4) are scheduled to commence in late 2024, allowing sufficient time for iterative adjustments and data-driven refinements throughout 2025. This structured timeline ensures progressive development and evaluation, aligning with the overall project milestones.