D8.1 VALIDATION RESULTS OF LOCAL ENERGY COMMUNITY SOLUTIONS

VERSION 1

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About ERA-Net Smart Energy Systems

ERA-Net Smart Energy Systems (ERA-Net SES) is a transnational joint programming platform of 30 national and regional funding partners for initiating co-creation and promoting energy system innovation. The network of owners and managers of national and regional public funding programs along the innovation chain provides a sustainable and service oriented joint programming platform to finance projects in thematic areas like Smart Power Grids, Regional and Local Energy Systems, Heating and Cooling Networks, Digital Energy and Smart Services, etc.

Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

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1 INTRODUCTION

As an essential element of the future energy system, energy community is introduced by EU's clean energy package. There are two types of energy community, the Renewable Energy Community (REC) and the Citizen Energy Community (CEC). The two community types are different in terms of geographic limitation, membership, energy sources and major purposes, etc (Palm, 2021).

The ERA-Net project CLUE aims to acquire knowledge on the optimized design, planning, and operation of local energy communities (LEC). Tailor-made solutions have been developed and demonstrated to support the operation of sustainable local energy systems / energy communities in Austria, Sweden, Germany and Scotland. The aim of the report is to summarize the validation results of the developed tools and lessons learnt during the demonstrations.

The content of the report is based on information collected in following ways:

- Questionnaire filled by each demo representatives.
- Two workshops for experience sharing.
- Other deliverables in CLUE.

Section 2 introduces the themes and organization of the two workshops. Section 3 gives an overview of the demonstrations and summarizes the validation results in each use case. Section 4 categorizes the lessons learnt from the demonstrations. The focus areas in the next step are identified and summarized in Section 5. The conclusion is given in Section 6.

2 WORKSHOPS FOR EXPERIENCE SHARING

Two workshops were organized to share experiences among the demonstrations. On the first workshop, the representatives from each country presented the status and validation results. On the second workshop, discussions were organized to summarize the key learns, propose recommendations, and identify future study areas. Following questions are discussed on the workshops:

Key learnings:

- What are the most important barriers identified in the demonstration?
- What are the most valuable lessons learned during the project?
- What are your top recommendations to upscale and replicate the solutions?

Road ahead:

- What are the flexibility areas/energy community solutions with highest potential?

- What are your organization’s next steps towards upscaling the solutions and unlocking the potential?
- What are the potential research ideas based on CLUE-findings?

Inputs from the two workshops are summarized in the report.

3 DEMONSTRATIONS AND VALIDATION

The demonstrations in the four countries emphasizes on different aspects of local energy communities. Table 1 shows an overview of the demonstrations regarding the concerned energy sectors, the developed and validated tools, and demonstrated use cases. Electricity is the main energy carrier addressed in most demonstrations, while district heating and cooling is focused on the German demo. The sector coupling issues between electricity and heating are investigated in both Germany and Sweden, while the balancing between electricity and hydrogen is explored in Scotland. The tested solutions are based on either local or cloud functionalities, supporting the use cases such as energy trading, demand response (DR), network security, capacity sharing and community currency. The use cases in the table are in accordance with the parent use cases defined in work package 3 for certain targets or applications. More detailed description of them can be found in D3.1(Person et al., n.d.) .

In the following subsections, the specific use cases and the corresponding validation results will be briefly introduced. According to the objectives of the CLUE project, the demonstrations have focused on proof of concept and technology in different LEC use cases. More explanation of the demos and validation can be found in deliverables[1] D4.1 for Austrian cell, D5.1 for Swedish cell, D6.1 for German cell and D7.1 for Scottish cell.

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[1] Deliverables D4.1, D5.1, D6.1 and D7.1 will be available on the project website https://project-clue.eu/deliverables/.

Table 1 Overview of local energy community demonstrations in the four countries

	Austria	Germany	Scotland	Sweden
Energy sectors	Electricity	District heating and cooling, sector coupling with electricity	Electricity and hydrogen	Demo 1, 3, 4: electricity Demo 2: electricity and district heating
Technical solutions / tools	Demo 1: AIT Rapid Deployment Platform Demo 2: Citizen Energy Community Payment System, Minerva Wallet	E.ON Ectogrid	Smart energy management platform: ScotCLUE Web of Cells	Demo 1: E.ON VPP (Virtual Power Plant) Demo 2-3: E.ON Ectocloud
Use cases	• Energy Trading • Control-based DR • Network Security • Community Currency	Energy Trading	• Energy Trading • Customer-based DR • Capacity sharing	• Control-based DR • Customer-based DR • Incentive-based DR

3.1 Austria

Both REC and CEC have been demonstrated in Austria. The demonstration aimed to verify flexibility potential of e-mobility integrated with central storage, intelligent energy management systems and flexible community tariffs. Furthermore, the concept of community currency has been tested using blockchain technologies.

Demo 1: The demonstration has taken place in Gasen, Styria. A REC was equipped with smart meters, energy management system, EV charging, PV and battery storage. A rapid deployment platform has been developed by AIT to deploy optimization and control algorithms, and exchange data within the LEC. The platform is modularized i.e., different functionalities and micro services are implemented into modules which are reusable in simulation environment or other LECs. In addition, each module could be programmed with different programming languages while using a common intercommunication interface.

The core controlling algorithm of the energy community is Grid Capacity Management (GCM), which considers the electrical grid constraints in the optimization and uses the results to control flexible resources. It also includes an accounting module to calculate the traded energy within the LEC and with the grid.

Data quality issues were found during the testing period e.g. missing data for active power, and unmatched current and voltage measurement. The poor data quality from energy assets has affected the performance of GCM and made it difficult to define constraints of the grid. The data quality issue was resolved by replacing with equipment from Siemens. A continue debugging and test of GCM will be carried out until the end of the project.

Demo 2: The demonstration was a proof-of-concept of Citizen Energy Community Payment System in Ollersdorf im Burgenland. For community members with an energy account, the energy flow ekWh was recorded in database and converted to tokens which were transferrable through a blockchain system. Community members can use the tokens for EVs charging or buying coffee. Four use cases have been tested in the demonstration:

- **Use Case 1:** Energy account / Community currency
- **Use Case 2:** EV-Charging payment with community currency
- **Use Case 3:** Community currency payment at 3rd parties
- **Use Case 4:** Fully automated EC accounting system

The payment system App, Minerva Wallet, is available on the Google Play Store. Participants in the pilot trail consisted of 33 private house owners, 2 small businesses and 4 municipality objects (town house, school, fire station, church office). Workshop were held for community members to install the digital wallet and test paying with the digital tokens. Their feedback shows that the concept of blockchain and crypto token was not familiar to ordinary people. The average age of people coming to energy community information events were 60+, and they were unfamiliar about how the new forms of currency function. In contrast, some younger users had no issue with the use of crypto tokens. A smaller minority (10-15%) was highly interested in the new tools and payment options. On the other hand, the solution needs to be simple for most community members.

3.2 Sweden

The aim of Swedish demonstrations was to verify the technical potential of flexibility from EV charging, power-to-heat and batteries. The demonstrations focus on deploying technologies to unlock and steer flexibility. Four demo sites have been included to reflect a large-scale LEC consisting of multi-family houses and other building types.

Demo 1: Test of flexibility using smart charging

Tests were carried out with 28 public EV charging points in two different multi-storey public garages. Three use cases were defined to test the reduction of charging speed under different condition. The control signals were sent through software Virtual Power-Plant (VPP) that has been developed by E.ON.

- **Use Case 1: Site based reduction**

  All active charging sessions are eligible for reduction. The use case was tested for two weeks.

  Use Case 2: Session based reduction

  Reduction is allowed if a charging session has been active for at least 1 hour and has transferred at least 2 kWh.

- **Use Case 3: Customer based reduction**

  Condition for reduction is based on previous data for individual customers. Reduction is allowed if a customer has been parked for 75 % of their average charging time, or if they have managed to charge 75 % of the average charging energy.

"Delivered Flexibility" was defined as KPI to validate the above use cases. The KPI was measured by collecting charging data from the charging stations and comparing with baseline. The average delivered flexibility was 0,67 kW/charging point in Use Case 1, 0,52 kW/charging point in Use Case 2 and 0,17 kW/charging point in Use Case 3.

Demo 2: Test of flexibility in a facility with heat pumps and district heating

The demonstration was at the Triangeln property which contains offices, restaurants, stores and living spaces. Both district heating and heat pumps have been installed in the property. The system control and data measurement were managed by ectocloud, a digital platform developed by EON.

- **Use case**: Heating from radiators is limited by adjusting the set temperature during limited periods for reducing the power for both heat pumps and district heating.

"Reduced electric power supplied to the heat pumps" was defined as KPI to validate the use case. Tests were carried out in December 2023 and relevant parameters were measured e.g. temperatures, electric power, district heating energy flows. The reduced electric power could reach 200 kW without affecting the comfort of tenants, which exceeded the effect expectation.

Demo 3: Stationary battery in a residential building

The demonstration took place in the student apartment building Rönnen. The control system EON ectocloud was used to steer the stationary battery while measuring the energy consumption of the building, imported energy from the grid, and charging/discharging of the battery.

- **Use case**: Using the stationary battery for peak shaving

The KPI defined for validating the use case was "electric power that the battery can provide for peak shaving". Control signals were sent to the battery and the observed performance was compared with the nominal parameters stated in the manufacturer specification. Initial tests showed that the maximal discharging power of the battery was 14,5 kW, which was lower than 24 kW as stated by the battery supplier.

Demo 4: Flexibility in construction site

The demonstration was at the construction site of Long Stay Hotel in Västra Hamnen, Malmö. The total electricity consumption of the construction site was measured as well as submetering of building cranes, building barracks and other onsite electricity. A simulation was done for estimating the benefit of renting batteries to reduce energy peaks. The simulation result shows that the energy storage could lead to a small cost saving although there are larger incentives to collect more knowledge about power demands on the construction sites.

3.3 Germany

The Germany demo was taken place at Shamrockpark in Herne. The aim was to implement and test a smart heating and cooling network with the core energy concept "ectogrid", a smart energy management system developed by EON. The demo planned to deploy the 5th generation heating network with industrial waste heat and a refrigeration plant as the major heat source. The demonstration also concerns sector coupling between heat and electricity by providing space heating and domestic hot water with decentralized heat pump.

A separate energy supply company was founded by the local municipal utility and EON for supplying energy to Shamrockpark. However, the planning and implementation have been delayed by a lengthy approval process. The pipeline from the neighbouring industrial company to supply industrial waste heat was built in 2022, but the effort was greater than expected considering the pipeline crossing under railway tracks. The retrofitting of the existing buildings was started in 2021 whereas the implementation of new buildings has been delayed caused by Corona pandemic among other things. Due to the delays and the changes in the construction sector, the owner of Shamrockpark, FAKT AG, had to file for insolvency in autumn 2022. Since then, the work has been stopped.

Therefore, the demonstration of the technologies could not be completed within the CLUE project . However, the scientific work was carried out successfully. This included an optimised planning of the ectogrid, the further development of a modelling tool and the calculation of external flexibilities of the neighbourhood. Furthermore, user behaviour was analysed during the development process.

3.4 Scotland

The aim of the Scottish demonstration was to develop a multi-vector platform, which can support the community-based energy management under different operational conditions. The platform was demonstrated at the trial site Levenmouth with wind turbines, community solar PV sites with stationary home batteries. The platform has been developed based on the Web of Cells concept, which enables managing one or a group of energy assets for achieving an objective or a series of objectives.

Three use cases were defined and tested in the demonstration:

Use Case 1: Maximise Renewables

The priority of this use case is to coordinate all energy assets to maximize consumption of local renewable generations from PV and wind turbines.

Use Case 2: Maximise Hydrogen Production

The priority of this use case is to maximize hydrogen production using local renewables sources i.e. PV and wind turbine and avoid using grid electricity to meet the hydrogen demand.

Use Case 3: Avoid Grid Network Constraint to Store Hydrogen

The priority of this use case is to avoid curtailing wind production during grid congestion period by transferring the excess wind power to electrolyser. This would continue until hydrogen storage is full and then the wind production will need to be curtailed.

In each use case, a set of governing rules was discussed and agreed among the partners in ScotCLUE. The three use cases were tested based on these rules. A dashboard was developed to control the operation modes/use cases and visualize the real-time status of the energy assets. Results in each use case could be observed from the dashboard showing e.g. when to charge/discharge batteries, the charging/discharging power of batteries, how much excess power is used to produce hydrogen, and how much wind production is curtailed in different scenarios.

4 LESSONS LEARNT

Besides the validation results, the CLUE partners also shared their experiences in the workshops. The lesson learnt during the demonstrations are summarized as below.

4.1 The degree of user acceptances varied among demos

Apart from the technical performance of the developed tools, user acceptance has also been investigated in the demonstrations. Feedback from end users is crucial for further upscaling and replicating the solutions, while different degree of user acceptance have been found in the demonstrations.

Positive: In the Scottish demo, the community had a general acceptance for carbon free (net zero) type of projects like CLUE. The positive attitude has been helpful in terms of allowing the concept test in the demonstration. In Swedish Demo 1 on smart charging, most interviewed EV owners were positive towards smart technology and showed willingness to contribute to grid stability by being more flexible when charging their vehicles. In Austrian Demo 2 with the CEC payment system, a small percentage of users (10-15%) showed high interest in the new payment option with the community currency.

Neutral: In some use cases user acceptance was not perceived as a problem such as in Swedish Demo 1 and 2. The testing results in Demo 1 suggested that user acceptance has not been a problem in the use cases because the vehicle owners did not notice when charging power was reduced. In tests of Demo 2, the heat pump power was decreased for a few hours without compensating with increased district heating. This did not lead to any significant effect on comfort due to thermal inertia of the building.

Hesitant: However, some hesitations from the end users have also been observed. In Austrian Demo 2, the blockchain and cryptocurrency concepts were found unknown and complicated for majority of energy community members. The solution is only for smart phone users whereas some people still use feature phones. In Swedish Demo 1, even though many people expressed interest and willingness to provide flexibility for vehicle charging, they also raised concerns about their capability to be flexible. The limited compatibility could be due to factors such as work patterns, household composition, technological assets and dependencies, health status and knowledge.

4.2 Many factors can affect the implementation progress

The progress and success of implementation could be affected by many factors, either positively or negatively.

Partner collaboration and stakeholder engagement

The importance of partner collaboration and community engagement has been underlined in the Scottish demonstration. "Working with the community was vital in allowing us to use the community centres as demonstrated sites. A good understanding of the region and community plans allowed us to make decision on how to develop the use cases. Good understanding and collaboration within the ScotCLUE partners also allowed us to achieve our desired outcomes and goals." said John Nwobu, Senior Research Engineer at ORE Catapult.

Unforeseeable causes of delay

Delay of the implementation has been experienced to different extent in almost all demonstrations due to different reasons. In Swedish Demo 3 "Stationary battery in a residential building", installation of the battery and control system took much longer time than anticipated. "Having different companies responsible for different parts of installation can increase time manyfold, "said Peter Hallberg, management consultant at EON. The installation has also been delayed in the Gasen (Austrian Demo1) because of the supply shortage of electrical devices. Furthermore, the data quality problems and replacement of smart meters also prolonged the process. In the German demo, the urban development and the implementation of the neighbourhood in Shamrockpark were delayed due to e.g. Corona pandemic, long approval process for the new energy company, pipeline construction crossing railway, and finally stopped due to the insolvency of the developer. Nonetheless, the scientific objectives were essentially achieved by adjusting the timetable of the research work related to the energy aspects. "It is important that the scientific work can be decoupled from the implementation progress if necessary. Developing a plan B to complete the work should be possible in case other partners drop out of the project." said Gerhard Stryi-Hipp, researcher at Fraunhofer ISE.

4.3 Suggestions have been proposed to improve the solutions

As described in Section 3, the conceptual and technical solutions were validated in the demonstrations while some potential improvements have been identified. For example, the smart charging control was tested in Swedish Demo 1. The demo responsible pointed out that it is important to choose a software which is expandable and scalable for developing new functionalities. In the demonstration, the control rules have been applied for a group of chargers due to software issues, which made it difficult to validate and predict the change of charging behaviours. A better solution could be e.g. setting control rules for each charger individually. Furthermore, automation is important when scaling up the solution in terms of submitting flexibility bids to the local flexibility market and executing the load control.

In Austrian Demo 2, the energy flow ekWh was converted to tokens which could be used to pay for EV charging or coffee in the community. However, the demo responsible pointed out that theoretically the value of token shall change when energy prices changes. Therefore, it is important to closely follow the energy market to better represent the value of token within the community.

4.4 Business potential is difficult to validate

A general discussion on business models have been done in Task 3.1 and summarized in deliverable D3.1 (Person et al., 2021). However, it is not straightforward to verify the business potential for each demo. A priority of the demonstrations was to verify the technical solutions in various use cases whereas the overall economic potential is difficult to estimate. For example, A LEC can theoretically benefit from providing flexibility services, but the commercial value could only be realized when the aggregate flexibility can reach the minimum capacity requirement of the flexibility market. It is challenging for the small-scale demonstration to verify the actual market values without considering potential accessibility issues to the markets. Furthermore, uncertainties are increased in the dynamic environment. Unforeseeable factors e.g. the changing landscape in energy sectors may affect the business-relevant decisions in the project. In addition, the validations have been carried out for specific use cases, which have been defined by stakeholders according to the most interesting aspects for LECs. On the other hand, the overall value for the whole community is not clear yet. A thorough analysis is necessary considering the possible coupling of different use cases as well as the allocation of benefits and costs among community members.

4.5 Regulations affect the scope of demonstration and upscaling

A comprehensive assessment about the national transposition of the EU directives on energy community in the four countries were carried out in Task 3.4. This subsection highlights some specific aspects related to the demonstrations that have been emphasized by partners during the workshops.

Legislation for energy communities in the sense of energy sharing has not yet been implemented in Germany. Therefore, the concept of electric energy sharing could not be demonstrated. However, research has been carried out to assess how energy communities with energy sharing could improve the operation of an electricity-heat-energy system. It was found that supplying decentralised heat pumps with electricity to produce heat in an energy community with energy sharing would be very beneficial. This proves that energy communities do not only make sense in the electricity sector. However, this requires further development of German legislation. This means that awareness should be raised about the heat sector as an issue for energy communities. A comparison of the results of the German cell with the results of other demos is hardly possible, as there was a different focus.

Swedish Demo 1 shows that a large potential for flexibility can be expected when many charging points are aggregated. On the other hand, it is still perceived more profitable for DSO to invest in grids instead of pursuing flexible solutions. This is mainly due to the financial regulations for DSOs i.e., the revenue cap is related to the asset base (Pihl et al., 2020). DSOs are allowed to earn a specific rate of return for the value of investment. Therefore, they tend to favor capital expenditure in network infrastructure which can lead to an expanded asset base rather than e.g. procuring flexibility services on flexibility markets.

In Austria, a clear regulation exists on regional currencies. But cryptocurrencies are treated differently i.e., a separate authority oversees the qualification case by case. This has limited how the community currency is transferred in the Austrian Demo 1. In the demonstration, the tokens have been only allowed to use e.g. in the coffee shop inside the community which actually gifted coffee for free instead of having a real Euro account. EU plans to introduce a regulatory framework on crypto assets in 2024 which is expected to facilitate digital community currencies in both RECs and CECs. The Austrian regulation also requires that the generation and consumption data should be available to LECs/third party for accounting purposes. However, the digitalization process by DSOs have been slow and it was only available to form a CEC in a grid area operated by one DSO during the demonstration period. Enabling the data transferring between DSOs and other parties is important for upscaling the solution.

5 FOCUS AREAS IN THE FUTURE

Based on the results achieved in CLUE, several focus areas have been identified by project partners and will be further investigated in the future.

The onboarding/offboarding process for LEC members and the operation of LECs shall be smoother and easier than nowadays. **Digitalization and technique development** in following aspects are considered as important factors to facilitate the procedures and enable LECs as a form of active distribution grid:

- Digital platforms to lower the barrier for new entrants to LECs.
- Better visualization of real-time measurement e.g. production, consumption, storage and energy flow.
- Standardized and commercially viable ICT solutions which are affordable for ordinary households.
- Unified communication interface to allow the reconfiguration of energy assets and operation rules.
- Automatic functions to aggregate flexibility from e.g. heat pumps, EV charging, and provide service to DSOs or on flexibility markets.

Besides the further digitalization and technique development, the partners also highlighted the needs for more studies on **business model and market proposition** of LECs, considering the specific market rules and different setup of LECs in terms of infrastructures, stakeholder composition and local regulatory framework:

- Understand existing and future market mechanisms, and how it may affect the market potential of LECs.
- Investigate and compare different ways to operate LECs e.g. realizing the energy/capacity sharing in physical v.s. virtual manners
- Further explore opportunities, business models and values offering to different types of LECs with varied stakeholder compositions.

Furthermore, partners also expressed the willingness and plans to scale up the demonstrated solutions towards more community sites, higher degree of DSO/DNO involvement, and integration of multi energy vectors. The importance of international collaboration and knowledge sharing among countries were also highlighted.

6 CONCLUSIONS

The report provides an overview of the validation results of the LEC demonstrations in Austria, Sweden, Germany and Scotland. The LEC concepts and solutions have been verified in various use cases. Lessons learnt in the implementation and demonstration phases are summarized with the consideration of customer acceptance, impacts of regulatory framework, business values, potential improvement in technical solutions and factors affecting the implementation process. Based on findings in the project, several focus areas and plans in the next step have been identified by partners concerning the further technique development, market potential and business model investigation, solution upscaling, and further knowledge sharing and collaboration among EU countries.

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