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User-Centered Solutions for Digital and Sustainable Energy Communities

Final Report

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1 Introduction

The UCERS project (User-Centered Solutions for Digital and Sustainable Energy Communities), funded through Austria’s “Vorzeigeregion Energie” program, was conducted over a four-year period from March 2021 to February 2025. The project responded to the legislative introduction of energy communities (EC) in Austria and the accompanying need for practical, technical, and social support mechanisms to implement these frameworks effectively. The overarching aim of UCERS was to develop, test, and evaluate user-centered solutions that could enable the establishment and scaling of digital and sustainable ECs. Through a multi-disciplinary and trans-sectoral consortium, the project combined digital tool development, empirical fieldwork, participatory research, and policy-relevant analysis. The project focused on electricity, as this was the primary domain supported by Austria’s initial legal framework and existing public infrastructure. While heating represents an important aspect of the energy transition and holds future potential for energy communities, its integration—particularly with respect to measurement and data infrastructure—remains at an earlier stage of development.

UCERS was organized into several interlinked work packages. These included the development of digital infrastructures to support EC operation (Work Packages 3 and 4), the implementation of real-world testbeds across diverse building types and ownership models (Work Package 6), the design of participatory and co-creative engagement processes (Work Package 2), and the construction of an evaluation scheme to assess EC contributions to ecological, economic, and social sustainability (Work Package 5). The project also incorporated comparative and longitudinal analyses to capture the evolving expectations, experiences, and practices within the EC landscape. Work Packages 1 and 7 focussed on project management and dissemination/interpretation respectively.

One of the project’s central technological outcomes was the Community Data Exchange Platform (CDEP), which provides a user-friendly interface for joining, managing, and participating in ECs. Built on existing Austrian infrastructure, the CDEP integrates informational resources, project initiation tools, and administrative features such as contract management and member dashboards. In parallel, the Community Operation & Optimization Platform (COOP) was developed to support ongoing technical coordination within ECs. This system integrates monitoring, automation, and optimization functionalities and was adapted from existing software solutions provided by technology partners. Both platforms were tested and refined through scenario-based trials and testbed implementations, offering insights into digital support mechanisms under operational conditions.

Empirical work within UCERS also included two major survey campaigns. An early-phase study focused on initial user expectations and motivations among EC participants—many affiliated with project partner-supported initiatives—highlighted that financial considerations were the primary motivation for joining ECs. However, over time, respondents increasingly valued community, environmental, and regional benefits. A later, more comprehensive study expanded this perspective by assessing sustainability performance across a more mature and diverse set of ECs. This included the development and application of an evaluation scheme built around 22 criteria grouped into seven overarching categories.

Survey findings revealed several key patterns. ECs consistently performed well in areas related to affordability and member satisfaction, often delivering below-market electricity prices and fostering positive perceptions of participation. However, there were notable gaps in implementation related to inclusivity, education, and ecological initiatives. The evaluation scheme also identified misalignments between stated priorities and operational practices—for example, while environmental sustainability and regional development were often rated as highly important, corresponding activities were not always realized in practice.

Technical evaluations from the project's testbed environments further illustrated the variability of EC performance. Even baseline configurations without complex optimization achieved self-sufficiency rates of up to 40%, suggesting that meaningful benefits can be delivered with relatively low entry barriers. More advanced configurations, incorporating forecasting tools and energy storage, showed increased self-consumption and system efficiency, although these required greater technical capacity and investment. Simulated scenarios further supported the potential of intelligent energy management and storage optimization to improve overall performance.

Despite these promising developments, the project also identified structural and regulatory barriers. These included legal ambiguities surrounding participation by apartment owners, limited interoperability of digital tools, and administrative burdens that fall disproportionately on volunteers. Governance challenges were also observed, particularly around member engagement, decision-making, and equitable benefit distribution. Divergences between EC types—such as Local and Regional Renewable Energy Communities versus Citizen Energy Communities—highlighted how different organizational models shape priorities and implementation capacity.

Based on these insights, UCERS formulated a series of recommendations to support the further development of ECs in Austria. These include improving legal clarity for different community types, expanding support for participatory governance, investing in inclusive outreach and education, and strengthening technical infrastructure through interoperable digital tools. Additional measures include fostering exchange platforms, piloting novel EC configurations, and integrating ECs more systematically into national sustainability and energy planning. Specific emphasis was placed on recognizing and supporting volunteer engagement, which remains a foundational element of most operational ECs.

The UCERS project provides a comprehensive and empirically grounded assessment of the opportunities and challenges facing Energy Communities in Austria. Its findings underscore the importance of aligning technical development with social engagement, and of supporting community-driven energy transitions with robust legal, digital, and evaluative frameworks. The project offers a transferable model for designing inclusive, sustainable, and scalable ECs—contributing valuable evidence to inform national and European energy policy in the years ahead.

2 Content Presentation of Work Packages

2.1 Work Package 2: Customer and Stakeholder Participation

As part of the UCERS project, a comprehensive study was undertaken to explore how citizens and relevant stakeholders perceive, engage with, and experience participation in energy communities in Austria. The aim was to better understand the motivations for participation, perceived benefits and challenges, and the role that digitalization and community-building efforts can play in supporting broader uptake. This research directly informs the development of user-centered digital tools and contributes to more inclusive and effective EC implementation strategies.

This section presents findings from one of two major empirical studies conducted within the project. The first survey (Q4, 2023 – Q1, 2024) was carried out early in the implementation of Austria's EC framework and focuses on participants from communities primarily supported by the project partner neoom. These communities represent some of the first operational ECs in the country, offering valuable insight into early motivations, expectations, and practical challenges. A second survey from Q3–Q4 2024, covering a broader and more diverse set of ECs, is presented in Section 2.4. Together, the two surveys provide complementary perspectives on the evolution of EC participation and sustainability ambitions in Austria. A mixed-method approach was used for this first study. A quantitative survey was distributed to prospective and existing EC members (in cooperation with project partner neoom), and this was combined with qualitative interviews with selected participants to explore experiences in more depth. In addition, expert interviews were conducted with EC founders, operators, and digital service providers. While the findings reflect early impressions from some of Austria's first operational energy communities—developed during a period of historically high energy prices—they offer a valuable snapshot of the country's initial experiences, while also providing insights into the current landscape and future opportunities.

A central finding from the citizen survey is that financial considerations were the most frequently cited reason for joining or considering membership in an energy community. This insight is based on responses from 174 individuals, including both current members and prospective participants affiliated with neoom-supported ECs. Among this group, economic factors—particularly the potential for cost savings—were mentioned significantly more often than other motivations such as environmental benefits, energy autonomy, or community belonging (see Figure 1).

Within the sample, approximately 25% of respondents identified as prosumers—individuals who both generate and consume electricity—while the remaining 75% reported being consumers only. The demographic profile of respondents was not fully balanced: a large majority identified as male, most lived in owner-occupied housing in rural or semi-rural areas, and there was a clear tendency toward higher income and education levels. While the survey was designed to be inclusive, the resulting sample likely reflects the characteristics of early adopters of energy communities in Austria. This is further supported by qualitative interviews, which suggest that many current participants may have technical backgrounds or prior exposure to energy systems and digital tools.

It is also important to note that several demographic groups may be underrepresented in this study, including tenants, individuals with lower income or educational attainment, younger participants, and people of all genders not currently well reflected in early EC participation. Additional efforts will be needed to better understand the motivations, needs, and challenges faced by these groups. As such, findings from this work package should be interpreted with caution, bearing in mind that they primarily reflect the perspectives of early-adopters rather than a representative cross-section of the general population.

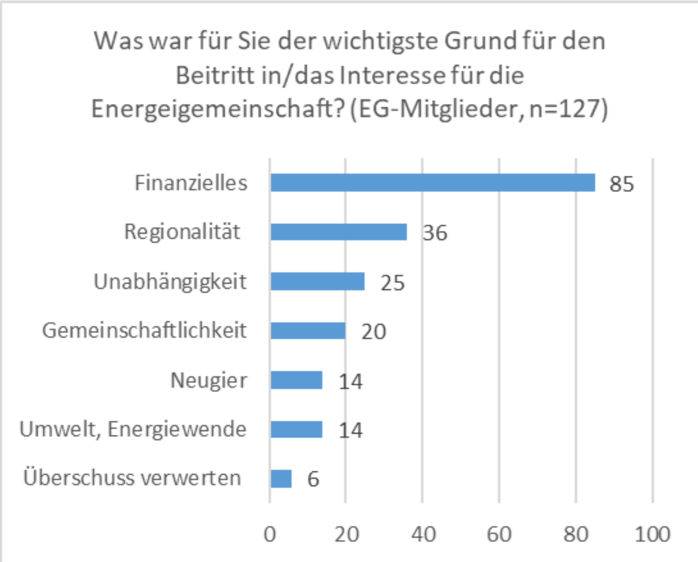

Figure 1: Main Reason for Joining EC - EN Title: What was the main reason for joining or being interested in an energy community? German-terms listed top to bottom: financial, regional, independence, solidarity, curiosity, environmental, sale of excess power (FHTW).

Despite the relatively narrow respondent profile, the study nevertheless reveals several noteworthy patterns—particularly when comparing participants' initial motivations with their experiences over time. While financial savings were the dominant reason for joining, many participants either did not identify a clear benefit or pointed to other values they came to appreciate only after joining. A substantial number of respondents explicitly stated that they had not yet experienced any tangible benefit, while others highlighted regional identity or community aspects as emerging positives. This divergence between expectations and outcomes is illustrated in Figure 2 and underscores the need for clearer communication about what EC participation entails and what types of benefits can realistically be expected in the early phases.

It is important to interpret these results within the broader context of early implementation. Many of the surveyed ECs were established at a time when Austria's national infrastructure—particularly in terms of smart metering systems and backend data platforms—was still undergoing development and deployment. As a result, some of the potential benefits of participation may not have been fully realized or made visible to participants at the time of data collection. Furthermore, the findings highlight the importance of setting realistic and transparent expectations during community formation. Overstating anticipated financial or technical benefits can risk disappointment and undermine long-term engagement, particularly when early operational challenges are still being resolved.

Figure 2: Greatest Benefit of Joining EC - EN Title: What do you consider to be the greatest benefit of joining an energy community? German-terms listed from top to bottom: financial advantage, no advantages, solidarity, regional, independence, environmental, knowledge/experience gained (FHTW).

The findings also point to untapped potential in the social and community dimensions of energy communities. While only a minority of survey participants reported knowing other members personally, many expressed a strong interest in improving this aspect. When asked about preferred forms of engagement, respondents showed the highest interest in attending informational events related to energy topics or community developments. There was less enthusiasm for more hands-on or time-intensive forms of participation, such as volunteering or organizing activities. However, a sizeable group indicated willingness to support their EC in more accessible ways, such as helping to recruit new members or contributing to small-scale tasks (see Figure 3). These results suggest that while ECs are not yet functioning as strong social networks for most participants, there is latent interest in more community interaction—particularly when opportunities are low-threshold and relevant to members' capacities and interests.

At the same time, it is important to note that the ECs included in this study were relatively early in their development. Newer initiatives have emerged (e.g. Robin Powerhood) that appear to be placing a stronger focus on social cohesion and inclusion and are reportedly gaining traction both in terms of membership and responsiveness to broader social goals. While there were no resources within the UCERS project to investigate these cases in detail, they point to promising directions for the future development of ECs in Austria—particularly where social dimensions are integrated intentionally from the outset.

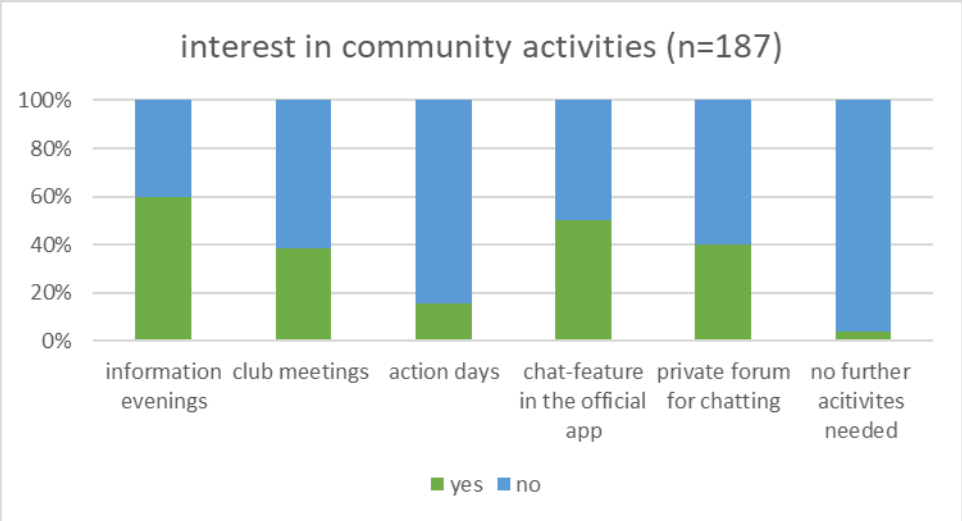

Figure 3: Interest in Community Activities - Interest in community activities of (prospective) EC members (FHTW).

Interviews with EC operators and other stakeholders added important context to the user findings. Operators reported that misunderstandings about the role and structure of ECs are a frequent cause of dissatisfaction or withdrawal, particularly when new members assume the EC functions like a conventional electricity provider. The interviews highlighted that bottom-up initiatives—those formed by local residents or civic groups—tended to achieve better community cohesion and engagement than top-down projects initiated by service providers or municipalities. However, all models face challenges in ensuring transparent communication, managing technical complexity, and aligning expectations with actual benefits.

Digitalization was widely seen as both a challenge and an opportunity. While the development and integration of digital tools—such as billing systems, load management interfaces, and member dashboards—remain hindered by a lack of standardization and complex interfaces with grid operators, there was broad agreement that such tools are essential for scaling ECs and reducing administrative effort. Experts noted that once citizens decide to participate in an EC, they generally show willingness to engage with digital tools, especially if those tools offer clarity, transparency, and ease of use. Barriers such as data protection concerns were viewed as manageable, though efforts are still needed to ensure accessibility across diverse user groups. Sections 2.2-2.3 outline the digital tools developed within the UCERS project, which aim to address these challenges and help unlock the potential of digitalization to support efficient, scalable, and user-friendly energy community operations.

Finally, the study explored how ECs might contribute to broader goals of social inclusion and energy equity. While this is not yet a defining feature of most current ECs, there was some support—particularly in the survey—for differentiated tariffs that could assist financially vulnerable households. Interviewees emphasized that such measures must be carefully framed to ensure fairness and avoid discouraging participation from other user groups. This area may offer room for further innovation in the design of inclusive EC models.

In summary, this early-phase analysis reveals that energy communities in Austria were initially driven by expectations of financial savings, though many participants later came to value less tangible benefits such as regional identity and shared purpose. At the same time, significant challenges emerged, including limited social cohesion, barriers to understanding the role of ECs, and underrepresentation of key demographic groups.

Importantly, these findings should be interpreted in the context of an evolving policy and infrastructure landscape. At the time of founding these energy communities, Austria's smart metering systems and billing capabilities were still maturing, which may have limited the visibility and realization of certain benefits—particularly for participants focused on short-term economic returns. Nevertheless, these pioneering communities played a crucial role in testing early implementation models and highlighting areas for improvement.

2.2 Work Package 3: Concept Development for Community Data Exchange Platform

As part of the UCERS project, a central aim was to design and implement a digital platform to support the creation, participation, and ongoing management of energy communities in Austria. With the legal framework for such communities still relatively new, there was a clear need for accessible tools that could help individuals and organizations navigate the associated technical and administrative processes. The resulting Community Data Exchange Platform (CDEP) was developed and refined as a core outcome of Work Packages 3 and 4.

Available as an online platform, the CDEP is designed to serve as a central resource for anyone interested in joining, founding, or managing an energy community. The user interface is structured around multiple interconnected components, each supporting a different stage in the user journey—from basic orientation to advanced administrative functions. It can be found at: https://ecommunity.at. Below is as brief description of its features.

Homepage: The homepage serves as the platform's entry point, providing a brief overview of its purpose and navigation to all key sections. It includes links to informational pages, the project list, and the people search function, offering users a starting point tailored to their interests or level of familiarity with the topic.

Project List: The project list allows users to browse existing or developing energy community initiatives. Each project entry includes basic details such as community type, energy source, location, and membership needs. A robust filtering system enables users to search by technical parameters, location, social goals, or energy demand.

Project Page: Clicking on a listed project leads to a dedicated project page, where users can find detailed information about the initiative, including its goals, operational status, and contact details. This page often serves as a gateway to the onboarding process and the pre-check tool.

Pre-check Tool: The pre-check tool helps prospective members assess their technical eligibility to join a specific energy community. By entering grid-related information and basic energy consumption or generation data, users can quickly determine whether they meet key requirements.

Sign-up Wizard: To simplify the registration process, the platform offers a sign-up wizard that guides new members through the necessary steps. Users can complete, sign, and upload required forms and contracts directly through the interface, making onboarding more accessible and efficient.

Project Wizard: For individuals or organizations looking to start a new energy community, the project wizard provides step-by-step assistance. It supports users in setting up a project page, defining participation criteria, and preparing necessary documentation for future members.

Dashboard: Each registered user has access to a personalized dashboard that displays key information such as energy usage, consumption trends, and billing history. The data is securely integrated from Austria's Energy Data Exchange (EDA), with privacy protections in place to ensure user confidentiality. Administrative Tools: A suite of administrative tools is available for community maintainers, including role management, membership administration, project page editing, and financial tools for billing and credits. These tools are accessible only to users with the appropriate roles and permissions, ensuring clear delegation and secure management.

The platform was shaped by ongoing user feedback and scenario-based testing, with a clear emphasis on usability, clarity, and flexibility. While the platform may evolve further, the current version already represents a foundation for practical, scalable support of energy communities in Austria.

By integrating technical, administrative, and social functions into a cohesive platform, the Community Data Exchange Platform contributes directly to the UCERS project's broader mission: to support inclusive, sustainable, and citizen-driven approaches to the energy transition.

2.3 Work Package 4: Hardware and Software Development and Testing

In parallel with the development of the Community Data Exchange Platform (CDEP), the UCERS project addressed a further key challenge: the operational and technical coordination of energy communities once they are established. While the CDEP supports administrative setup, data exchange, and participant onboarding, additional tools were needed to manage day-to-day energy flows, optimize system performance, and enhance user engagement.

To this end, the project introduced a dedicated component referred to as the Community Operation & Optimization Platform (COOP). The COOP denotes a set of digital functionalities developed and adapted during the project to support real-time energy management in distributed community settings. This work was carried out in close collaboration with two technology partners, each contributing solutions within their respective areas of expertise—including monitoring, control, automation, and energy optimization.

Drawing on their existing technical foundations, the partners further developed and adapted software and hardware components to meet the unique needs of energy communities. These efforts were informed by practical requirements and tested in real-world environments, with a focus on flexibility, interoperability, and user accessibility. As a result, the COOP framework emerged as a modular approach, combining backend control capabilities with participant-facing tools that enable transparency, responsiveness, and local optimization.

2.3.1 Local Energy Optimization & Community Management

As part of the Community Operation & Optimization Platform (COOP) activities within UCERS, neoom focused on improving local energy coordination and user interaction through the adaptation and further development of existing software and hardware systems. These tools were used to support both individual and collective optimization within energy communities and were deployed in a real-world testbed to assess their functionality under realistic conditions.

Several digital components were integrated and tailored to fit the specific context of energy communities. Contributions from neoom included:

- A local energy management platform was used to coordinate generation, storage, and consumption at the level of individual households or metering points. See Figure 4.
- A community coordination layer facilitated participant registration, billing processes, and overall community organization.
- A hardware interface gateway enabled smooth communication between distributed energy technologies—such as PV systems, batteries, heat pumps, electric vehicle chargers—and the digital control layer.
- A mobile and web-based user interface provided participants with real-time access to energy data, including consumption, generation, and storage metrics.

These tools were adapted to function within various testbeds and formed the basis for operational strategies aiming to enhance self-sufficiency, forecast-driven energy management, and participant engagement. Together with 4ward Energy Research GmbH, forecasting models were analyzed to improve consumption and production planning based on weather and historical usage data. These models can be especially useful under dynamic electricity pricing schemes and variable renewable generation conditions, helping to align local energy use with optimal operating strategies.

Participants had access to individual and community-wide metrics through the interface, helping them track and understand their energy behavior. Features included energy usage summaries over selectable time intervals (e.g., 7, 30, or 90 days), real-time feedback on current generation and consumption, and personalized recommendations. These features were designed to promote greater awareness, foster active engagement in local energy trading, and encourage energy-saving behaviors.

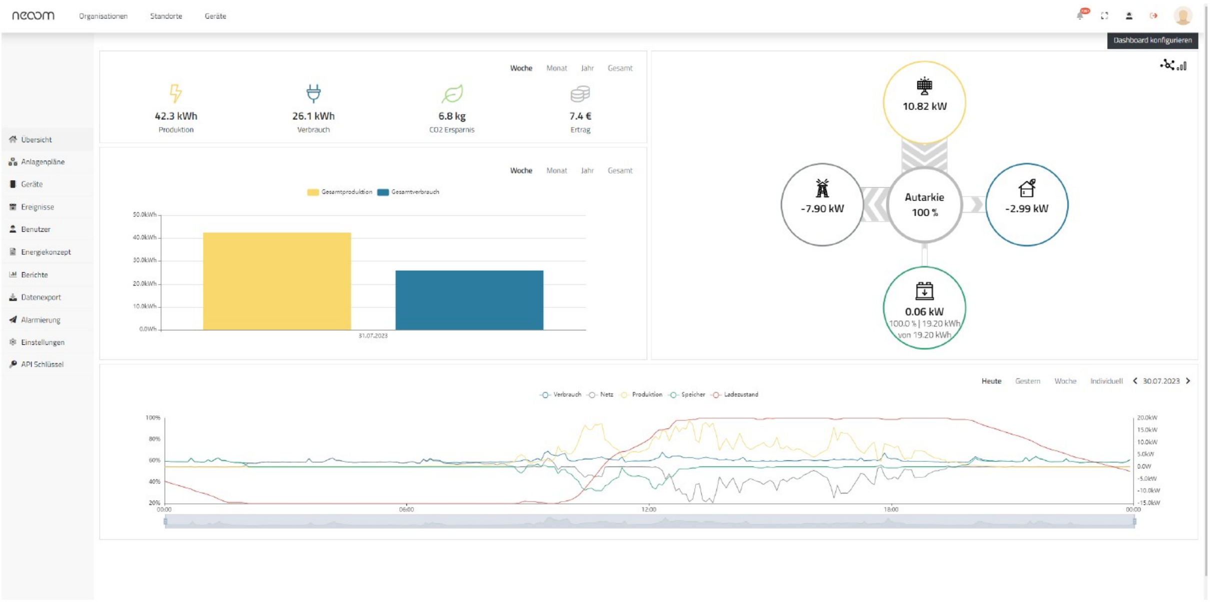

Figure 4: Example of Energy Community Monitoring from neoom (neoom).

Beyond technical optimization, the solution also supported administrative processes such as participant onboarding, billing, and data collection required for regulatory compliance. Interfaces with grid operators were included to streamline integration with existing infrastructure. Importantly, the operational costs of running such a community—including digital services—were made transparent to participants.

2.3.2 Monitoring, Control, and User Interaction

Another contribution to the Community Operation & Optimization Platform (COOP) within the UCERS project focused on energy system monitoring, control automation, and interactive user interfaces. This work was led by Reisenbauer Solutions GmbH, drawing on its prior experience in real-time energy management and control systems. Existing tools were further developed and adapted to the needs of energy communities and implemented in a residential testbed to evaluate their performance and usability. The partner's contributions included:

- A real-time monitoring system adapted to collect, process, and visualize energy data from distributed sources, providing the technical foundation for both operational oversight and user engagement.
- A control and automation layer capable of integrating a wide range of devices—including energy consumers, producers, and storage units—into a unified management framework.
- An interface with charging infrastructure, supporting integration of electric vehicle charging into the community's broader energy management strategy. See Figure 5 for an example.
- A dashboard system offering users personalized access to energy metrics, as well as tools to visualize and adjust behavior based on system status. See Figure 6 for an example.

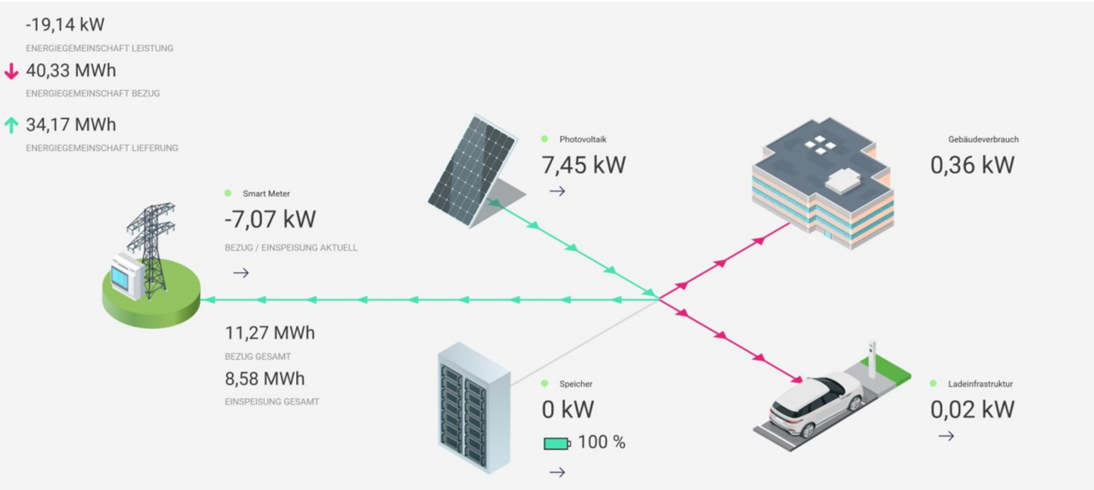

Figure 5: Single Member Energy Profile - Detailed view of a single member's energy profile, showing personal generation, consumption patterns, storage utilization, and contribution to community energy exchange (RSO).

These elements were implemented in a residential energy community to coordinate local energy use, enhance transparency, and encourage user participation. Monitoring tools provided insights into overall and individual power flows, supporting both operational decisions and long-term planning. The platform helped align consumption with local renewable generation, reducing dependence on grid electricity.

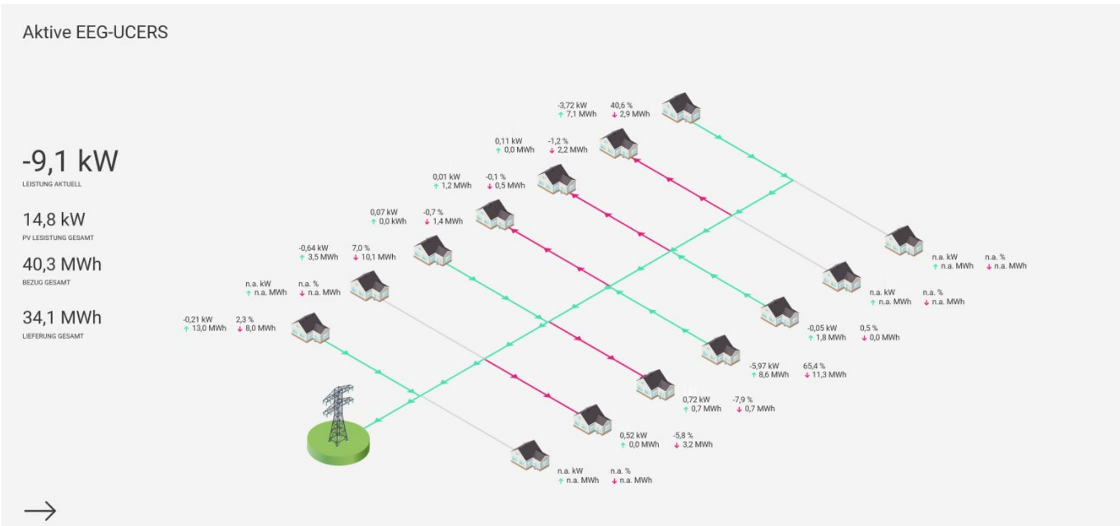

Figure 6: Dashboard: Production & Storage - Energy community dashboard for the COOP, displaying energy production, consumption, & storage activity (RSO).

To improve the user experience, interface designs were made accessible and intuitive, including real-time notifications and visual summaries. These tools helped participants monitor their energy behavior, understand their contributions to the community, and identify opportunities to improve efficiency. For example, real-time dashboards displayed live inflows and outflows of electricity, while historical overviews allowed for longer-term analysis of energy trends.

From a technical standpoint, the system proved scalable and adaptable. The ability to work with a variety of hardware configurations—without requiring major infrastructure changes—positioned the solution as a flexible option for similar communities. As with other components of the COOP, lessons learned through this deployment informed recommendations for future improvements, including enhanced predictive functions and broader integration with national energy data systems.

The testbed implementations highlighted the ability of the system to deliver individual and aggregated energy data, helping to identify inefficiencies, demand peaks, and optimization potential. This included tools to encourage flexible load shifting—such as timing consumption with periods of low-cost or high-renewable availability—and dashboards to communicate community performance metrics. For further details on technical implementation, system performance, and user feedback, refer to the relevant monitoring sections later in this report, particularly Section 2.5.

2.3.3 Integration of Energy Storage

As part of the UCERS project, a detailed simulation study was conducted to assess how residential battery storage systems can improve energy community performance. The analysis focused on five prosumer households, each equipped with a photovoltaic (PV) system but not yet using a storage unit. For each household, the installation of a 20-kWh battery was simulated under different operational strategies to evaluate the impact on local energy use and economic outcomes. The study examined electricity produced, consumed, and sold, applying a representative tariff structure that included: 29.60 ct/kWh for grid electricity, 18.2 ct/kWh for intra-community consumption, 10 ct/kWh for energy fed into the community, and 6 ct/kWh for feed-in to the public grid (EVU). This pricing framework enabled the evaluation of both individual cost savings and community-level energy performance under various storage operation scenarios.

Three battery storage scenarios were analyzed:

- **SN0: Baseline (no storage)**: Reflects the actual historical state of energy distribution without any storage system in place. This scenario serves as a reference point for evaluating the impact of storage-based optimization strategies.
- **SN1: Self-sufficiency optimization**: Local self-sufficiency optimization (storage used only for household needs). Storage is charged when surplus PV generation is available and discharged when household consumption exceeds generation. Decisions are based purely on energy balance at the individual household level, with the aim of maximizing local self-consumption and minimizing reliance on grid supply.
- **SN2: Self-sufficiency + community optimization** (storage used both locally and to discharge into the community): Builds on the self-sufficiency approach but incorporates economic optimization by considering the higher compensation rate available for energy fed into the energy community. Battery discharge decisions are informed by day-ahead forecasts and are not limited to meeting household demand—energy may also be discharged strategically to supply the community when demand exists, thereby increasing individual revenue.

The results showed that operating storage purely for self-sufficiency reduced the amount of energy available to the broader community. In contrast, adopting a community-oriented optimization approach significantly increased intra-community energy infeed—by as much as a factor of ten—resulting in higher revenues and greater local utilization of renewable energy.

Cost savings for individual prosumers were also higher (28–139 EUR per year) under the full optimization scenario (Self-sufficiency + community optimization), primarily due to the improved compensation rates for energy shared within the community. For example, a representative household (Prosumer C) increased its community infeed by approximately 1,500 kWh per year under community-optimized operation, clearly illustrating the benefits of coordinated storage management.

It should be noted, however, that these results are based on simulations assuming perfect forecasting. A more conservative estimate of the net gain for participating households—accounting for forecasting uncertainty and operational variability—would place the expected benefit in the range of €10 to €60 per year. Nevertheless, with the growing adoption of flexible tariffs by energy providers, these savings could increase in future applications.

At the community level, energy exchange increased by 700 to 3,000 kWh per year, depending on the structure of the system. This improvement in local energy balancing also reduced reliance on the external grid and contributed to more grid-friendly behavior—one of the central aims of modern energy communities.

2.3.3.1 Conclusions and Outlook

The simulation and forecasting activities underline both the potential and the limitations of predictive energy management in community settings. While forecasting household consumption remains challenging due to behavioral variability, solar generation prediction is much more robust—opening the door for forecast-informed storage control as a practical strategy.

Economically, the simulations showed that operating residential storage systems under a traditional self-sufficiency strategy can result in substantial tariff-based savings—approximately €360 to €610 per year, depending on the household's consumption and PV profile. These figures do not account for the cost of the storage system itself, a portion of which would need to be covered by the savings in a full economic assessment. Building on this, the analysis found that adding a community-optimized control layer—enabling forecast-based discharge into the energy community when demand and pricing conditions are favorable—can yield additional savings of €28 to €139 per year. These gains result from improved compensation for energy shared within the community and underscore the potential of coordinated storage management. In practice, the net benefit of this additional optimization is likely to be more modest, with a conservative estimate placing it between €10 and €60 per year due to forecasting uncertainty and operational variability.

Looking ahead, the financial outcomes for prosumers in energy communities could improve under more dynamic electricity pricing conditions. Time-variable pricing models, which are being gradually adopted by utilities and consumers, may offer additional opportunities for cost optimization—particularly as the number of hours with very low or even negative electricity prices increases, often during periods of high solar generation in summer months. The findings support the view that intelligent, community-oriented storage operation can become a central component of future energy communities. Predictive tools, combined with coordinated dispatch strategies, offer a scalable path toward greater autonomy and more efficient use of local renewable energy.

2.4 Work Package 5: Technology and Sustainability Assessment

Sustainable development encompasses a broad range of thematic dimensions, often referred to as pillars. These include ecological, economic, social, political-institutional, and cultural aspects. The most widely used framework is the so-called “magic triangle” of sustainability, which consists of the ecological, economic, and social dimensions, also known as the Triple Bottom Line (Purvis et al., 2019). However, there are differing views regarding the prioritization of these dimensions. In addition, goal conflicts often arise, where certain objectives are difficult to reconcile or may even be mutually exclusive (Kropp, 2019).

The integrative concept holds that, due to the complex interconnections between the dimensions of sustainability, sustainable development cannot be achieved through isolated, monodisciplinary changes. Instead, it requires a comprehensive and goal-oriented approach. For the development of an integrated evaluation scheme for sustainable development, the integrative approach proposed by Grunwald und Kopfmüller (2022) provides a suitable foundation. This is a cross-dimensional approach that does not rely on individual pillars or dimensions but instead defines goals and minimum requirements (rules) for sustainability based on the principle of justice.

2.4.1 Role of Energy Communities in Sustainable Development

With the adoption of the Clean Energy Package in 2019, the European Union incorporated the concept of energy communities into its legislation, specifically in the form of Citizen Energy Communities (CECs) and Renewable Energy Communities (RECs). The package aims to align the EU’s energy system with the objectives of the European Green Deal (Clean Energy Package, 2019).

The objectives and potential benefits of energy communities have been described by the European Commission as follows (European Commission, 2025a):

- A collective and citizen-driven approach in the energy sector to support a clean energy transition. At its core are the expansion of renewable energy and the improvement of energy efficiency at the local level.
- Promoting public acceptance of renewable energy projects and facilitating private investment in clean energy.
- Empowering citizens to actively advance the energy transition locally, enabling them to directly benefit from greater energy efficiency, lower costs, reduced energy poverty, and the creation of local green jobs.
- Enhancing system flexibility by encouraging civic participation through measures such as demand response and energy storage.

The use of renewable energy is often considered sustainable, as it contributes to strengthening regional economic structures, conserving resources, reducing environmental impacts, and increasing energy supply security, while also opening new opportunities for businesses (Ma and Wang, 2025; Ullah et al., 2024). Nevertheless, renewable energy generation can also have negative impacts on ecosystems, for example, by affecting flora and fauna or altering the landscape in the case of large-scale installations (Virah-Sawmy and Sturmberg, 2025). The expansion of renewable energy and the active involvement of energy communities in shaping the energy transition should therefore take place with particular consideration of sustainability criteria.

2.4.2 Methodology

The scheme is based on clearly defined criteria and indicators, which enable energy communities to assess the extent to which they contribute to sustainable development and identify areas where they are already well-positioned from a sustainability perspective.

The evaluation scheme (see Section 2.4.6) covered 22 sustainability criteria, grouped into seven overarching categories. Each criterion reflects a specific area of potential contribution by energy communities, such as Energy Consumption, Self-Sufficiency Rate, or Regional Value Creation. These were assessed through a set of qualitative and quantitative indicators, which—by design—signal whether a given criterion is being addressed or fulfilled. To ensure these indicators were accessible to survey participants, they were formulated as standardized questions and integrated into a structured survey. The aim was to determine whether, and to what extent, energy communities are engaging with these sustainability aspects in practice.

Many of the survey questions (indicators) were phrased in binary terms (e.g., whether a particular measure had been implemented). A positive response typically indicates that an indicator has been fulfilled in the sense that a concrete action has been taken—suggesting that the related criterion is being addressed. However, this should not be interpreted as full realization of the criterion. Rather, it signals that relevant efforts are underway.

Since the criteria and indicators are intended to guide ongoing engagement with sustainability topics, they are best understood as action-oriented reference points. Achieving 100% fulfilment of indicators within a category does not mean that sustainability has been “achieved” in that area. It simply reflects that energy communities are actively working on the issues grouped under that category, as defined by the indicators. The seven categories were used to structure the evaluation and to guide interpretation of the results (see Section 2.4.8).

The evaluation scheme was developed through an iterative, participatory process. The first three steps represent the conceptual and methodological foundations of the scheme. The final two steps illustrate its application and how the findings informed the derivation of practical recommendations.

Together, these five stages form the basis of the UCERS project's Work Package 5.

1. The process began with an integrative understanding of sustainability, which served as a normative guiding principle.
2. Based on this foundation, a set of sustainability criteria was developed to reflect the potential contributions of energy communities across ecological, economic, and social dimensions.
3. To enable practical assessment, each criterion was linked to one or more qualitative or quantitative indicators, which were formulated as standardized survey questions. While the survey was designed to be accessible to community members, care was taken to preserve the conceptual traceability of indicators back to the underlying criteria and categories, allowing for future academic use and further methodological development.
4. The evaluation scheme was then applied in a nationwide survey to determine the extent to which energy communities are addressing these criteria in practice and how they perceive their relevance.
5. Finally, insights from the assessment were used to identify potential goal conflicts and derive practical recommendations for decision-makers to support the strategic development of energy communities in Austria.

2.4.3 Development of Evaluation Criteria

The process began with the identification of evaluation criteria that reflect the intended areas of impact of energy communities. These criteria describe what ECs aim to achieve—such as social inclusion, ecological sustainability, or regional economic value creation—and provide a normative reference point for evaluation.

The integrative concept of sustainable development proposed by Grunwald and Kopfmüller (2022) served as the conceptual foundation. A literature review supported the expansion of the criteria and informed their initial grouping into categories.

In addition, the development of the criteria was guided by the following key questions:

- What problems do energy communities address?
- What goals do energy communities pursue, for example in terms of energy supply, inclusion, or sustainability?
- What is the scope of action for ECs, and how can they contribute to broader goals such as the Sustainable Development Goals (SDGs)?

The resulting draft was further refined through a transdisciplinary process involving the project team, scientific experts, and practice-oriented stakeholders.

2.4.4 Feedback on Criteria: Expert Interviews

Before finalizing the criteria, ten semi-structured expert interviews were conducted to validate the draft criteria and identify any thematic gaps. The experts came from diverse backgrounds, including:

- Renewable energy systems and concepts
- Energy technologies and legal frameworks
- Practical experience with energy communities
- Municipal implementation experience
- Research with a focus on energy communities
- Institutional coordination at the national level
- Social science analysis of energy communities
- Gender and diversity perspectives
- Advisory services and support for energy communities

Each interview lasted approximately 45 minutes and focused on the relevance and completeness of the criteria. While indicators for the criteria were not yet in place at this stage, feedback from the interviews informed the refinement of the criteria and the overall structure of the evaluation scheme.

2.4.5 Development and Pre-testing Indicators and Survey

Based on the refined criteria, indicators were developed to translate these into measurable elements, making the evaluation scheme applicable in practice. These indicators formed the basis for the survey questions later used in the nationwide survey of energy communities. See Section 2.4.7 for methodology and Sections 2.4.11-2.4.13 for results of the survey.

Throughout this process, particular care was taken to ensure clarity of wording and to avoid redundancy between indicators. Overlapping content was identified and removed where necessary to prevent double-counting and ensure the analytical integrity of the evaluation.

To ensure the indicators were appropriately translated into clear and comprehensible survey questions—while remaining applicable across diverse EC contexts—they were reviewed with one of the previously interviewed experts (see Section 2.4.4) in a pre-test phase. This plausibility check served to identify any unclear formulations or unintended overlaps and led to minor adjustments in wording. At this stage, the indicators were fully integrated into the evaluation scheme and ready for broader testing through a nationwide survey, described in Section 2.4.7.

2.4.6 Summary of the Evaluation Scheme

The development process described in the previous sections resulted in a comprehensive evaluation scheme. This scheme (see Figure 7) encompasses 22 Sustainability Criteria, organized into seven overarching Categories. These Categories form the first column of Figure 7and include:

1. Ecology and Health – e.g., energy consumption, renewable energy share, biodiversity, and landscape protection.
2. Self-Sufficiency and Supply Security – e.g., self-sufficiency rates, grid stability, local generation.
3. Affordable Energy and Economic Viability – e.g., price fairness, economic sustainability.
4. Regional Development – e.g., local value creation, public-benefit investments.
5. Education and Research – e.g., awareness raising, educational opportunities, research engagement.
6. Equal Opportunity and Inclusive Processes – e.g., inclusive decision-making, transparency, accessibility.
7. Community Benefit – e.g., quality of life and member satisfaction.

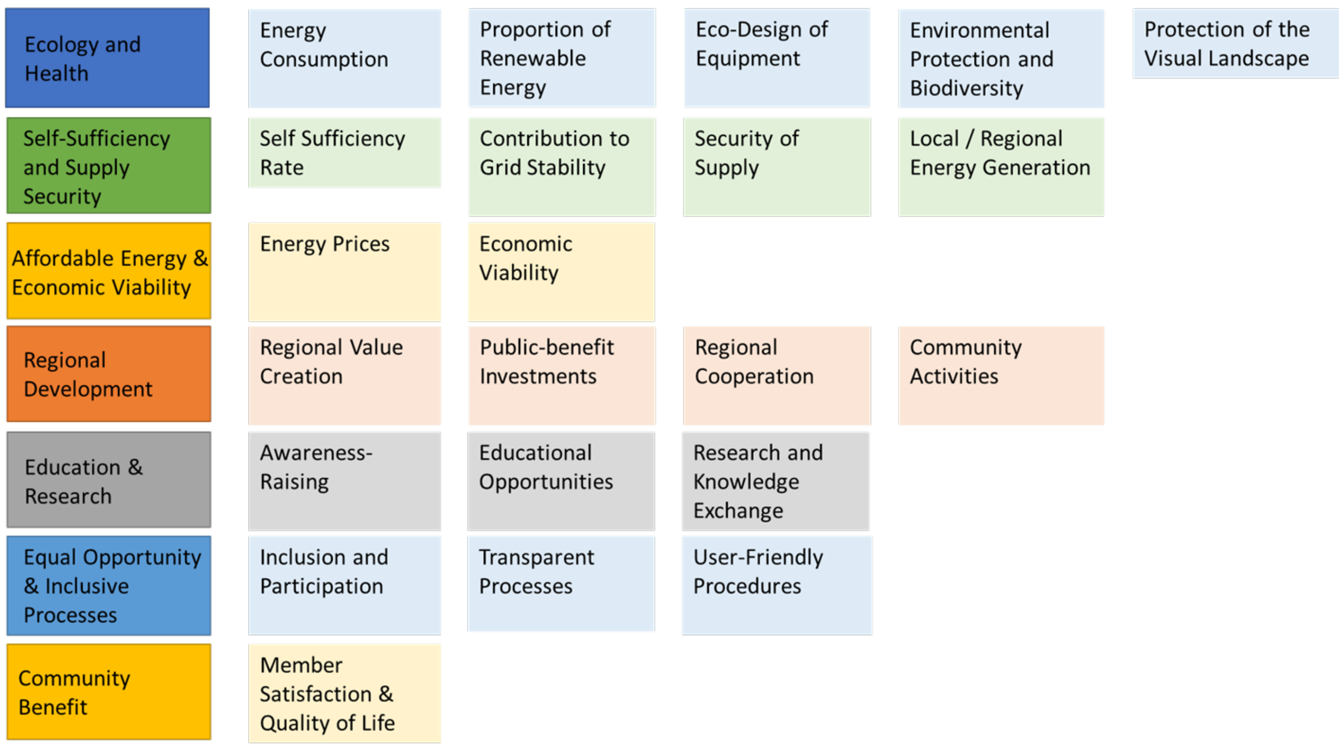

Figure 7: Overview of categories (left) and criteria (action areas) (right). (FHTW).

To support consistent interpretation, Table I provides definitions of key terms used throughout this report. These definitions clarify the structure and relationships between categories, criteria, and indicators, as well as their operationalization and role in the assessment. This reference is intended to assist readers as the report shifts from the scheme's development to practical application.

Table I: Key Terms in Evaluation Scheme - Definition of Key Terms in the Evaluation Scheme and Survey (FHTW).

Term	Definition	Example
Category	A broad thematic area that groups related sustainability criteria; used to organize and present results in a clear, consolidated form (e.g., in radar charts).	Category 2: Self-Sufficiency and Supply Security
Criterion	A specific action area relevant to EC sustainability, grouped within a category.	Criterion 2.1: Self-Sufficiency Rate within the above category.
Indicator	A qualitative or quantitative measure used to assess whether a criterion is being addressed or fulfilled.	Has your EC set a target for self-sufficiency?
Survey Question	A phrased form of an indicator used in the surveys to collect structured responses.	Does your EC use storage systems to manage load shifts?
Result (Fulfillment)	The degree to which the EC reports engaging in actions linked to a given criterion.	75% of ECs reported implementing local energy storage.
Self-Assessment	A subjective rating of how important each category is to the EC, based on participant perception.	Category rated 5/5 by respondents for importance.

2.4.7 Application of Evaluation Scheme Nationwide Survey

The evaluation scheme (Section 2.4.6) was implemented as an online survey using LimeSurvey. The indicators were translated into closed survey questions and distributed to more than 300 active participants in energy communities across Austria. Participants were encouraged to share the survey with other community members.

Each question could be answered with the following options:

- Applies
- Does not apply
- Not relevant
- No information available

The goal of the survey was twofold:

1. Assess whether ECs were engaging with the topics described in the criteria (based on their responses to the indicators).
2. Test the practical relevance and comprehensibility of the criteria and indicators themselves. Respondents were given the opportunity to provide free-text comments, which were later used to refine the evaluation scheme and inform recommendations.

To estimate the degree to which criteria were fulfilled within each category, the number of “applies” responses was divided by the total number of relevant responses. This allowed a percentage score to be calculated for each category. “Not relevant” and “no information available” responses were excluded from the denominator.

In addition, participants were asked to rate the importance of each category for their EC on a scale from 1 (very low) to 5 (very high). This self-assessment made it possible to compare how ECs perceive the relevance of various criteria with how consistently they appear to be implementing them.

A total of 59 responses were received, covering a broad spectrum of EC types and geographical regions. These responses formed the basis for the evaluation results and visualizations presented in Section 2.4.8., with the overall findings summarized in Sections 2.4.11-2.4.13.

2.4.8 Visualization and Feedback

The survey described in Section 2.4.7 was the main tool for applying the evaluation scheme. Responses were used to create radar charts that compare actual implementation with perceived importance across sustainability categories.

Radar charts were created for ECs that requested them (see example in Figure 8). Actual implementation was based on responses to indicators linked to specific criteria and categories, while perceived importance came from self-assessments rating the relevance of each category. These charts highlighted gaps between reported practices and stated priorities. Although they served as diagnostic tools, charts were not shown during the workshop; ECs could request their individual results afterward.

Free-text responses added insight into areas needing refinement. Based on this feedback, minor wording adjustments were made, and two potential duplications were resolved. The final version of the tool is designed for independent use by ECs—for internal reflection and long-term planning. Open comment fields for each criterion were also analyzed during a follow-up stakeholder workshop to refine findings. The evaluation does not directly measure outcomes like carbon reductions or economic returns. Instead, it assesses whether relevant practices, strategies, or structures are in place—signalling engagement with the sustainability criteria. It focuses on where action is occurring, not the scale or impact of those actions. Figure 8 shows a sample radar chart comparing actual implementation (blue) and perceived importance (orange) across seven categories. In this case, the EC focused efforts on Community Benefit, Equal Opportunity and Inclusive Processes, and Affordable Energy and Economic Viability. However, it rated Ecology and Health, Self-Sufficiency and Supply Security, and Regional Development as most important. The strongest alignment was in Affordable Energy and Economic Viability.

These results serve as a reflection tool for ECs, helping individuals or teams identify where their actual activities align with—or diverge from—their stated priorities. Discrepancies are not inherently good or bad; rather, they highlight areas where strategic intent and operational practice may differ. This can prompt valuable internal discussion, support more informed planning decisions, and ultimately strengthen an EC’s ability to align its efforts with its sustainability goals.

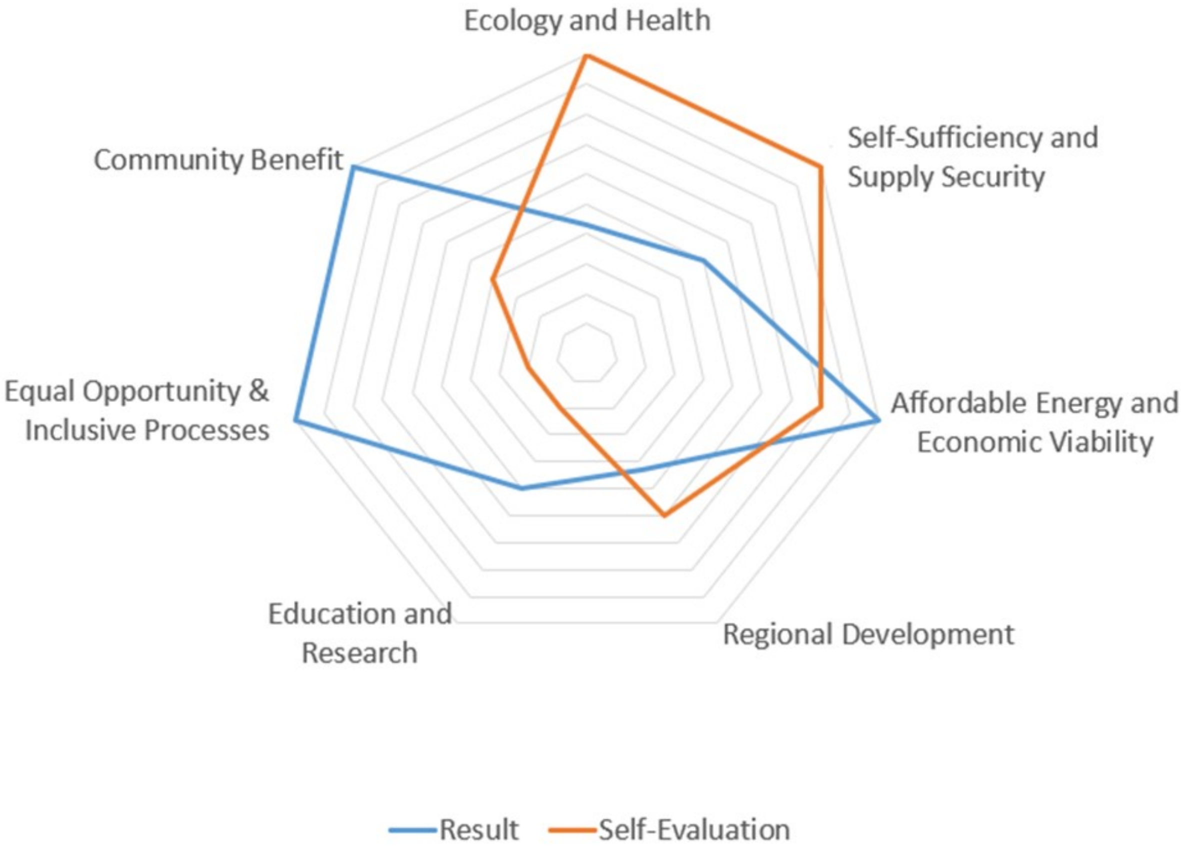

Figure 8: Case Example: Evaluation of an Energy Community (radar chart). The blue curve (Result) shows implementation based on aggregated indicator responses; the orange curve (Self-Evaluation) reflects self-evaluation of category importance from direct assessment of the survey participant (FHTW).

2.4.9 Stakeholder Workshop (Survey Follow-up)

To reflect on the usability and relevance of the evaluation scheme (Section 2.4.6) and to provide space for deeper discussion, an online workshop titled "Shaping the Future – Sustainable Pathways In and Through Energy Communities " was held. Participants from the survey were invited to attend. The workshop began with an introduction to the UCERS project and the aims of the evaluation scheme. The scheme and its methodology were presented, including a demonstration of the radar chart format. However, no individual or aggregate survey results were shared during the event.

Three EC representatives from different community models (LEG, REG, BEG) gave short presentations on their sustainability goals and challenges. These were followed by thematic breakout sessions, facilitated using the Padlet platform, focusing on the following topics:

- Technology, Economy, and Regional Development
- Environment, Education, and Equal Opportunities

Each breakout group was moderated, and participants actively contributed by posting, commenting, and discussing key points. The main insights were then summarized and shared in a concluding plenary session.

2.4.10 Post-Workshop Analysis and Derivation of Recommendations

Following the workshop, survey responses were analyzed by energy community type: LEG, REG, and BEG. For each group, the research team identified indicators with less than 90 percent agreement, suggesting differing interpretations or priorities across EC types. Particular attention was given to indicators with low levels of implementation but high perceived relevance, as these may highlight practical barriers or unmet needs within the communities.

All comments from the nationwide survey (LimeSurvey, Section 2.4.7) and the Padlet discussions were compiled into a structured summary table. This overview of common challenges served as the foundation for a set of practical recommendations aimed at policymakers and support institutions. The recommendations are intended to address the identified barriers and help better align support measures with the development goals of energy communities.

2.4.11 Assessment of Energy Communities Using Evaluation Scheme

Due to the limited number of responses, the results do not support statistically robust conclusions and should be viewed as exploratory, highlighting trends and potential research questions for future study. The findings are based on the national survey described in Section 2.4.7, which tested the evaluation scheme's practical applicability. The survey targeted board members and participants of energy communities (ECs) across Austria. A total of 59 individuals responded, representing 55 ECs—19 Local Renewable Energy Communities (LEGs), 34 Regional Renewable Energy Communities (REGs), and 6 Citizen Energy Communities (BEGs). Each participant completed the survey individually; board members received additional questions reflecting their organizational role. Responses were analyzed both across the full sample and by EC type. Aggregated results are discussed below.

Although the scheme supports aggregation at the criterion and category level, this was not applied to the full dataset. Given the early development stage of many ECs and the diversity of local contexts, the project team opted not to present aggregated fulfilment scores to avoid creating normative benchmarks or pressures toward standardization. Instead, the focus was on encouraging open reflection, supported by individualized feedback and qualitative interpretation. Aggregation was applied, upon request, for individual ECs wishing to visualize their results through radar charts. In such cases, the tool served as a diagnostic instrument for internal reflection and planning. Selected indicator-level results from the full sample still provide useful insights into implementation patterns. The summaries below highlight commonly reported practices and areas with limited engagement, based on individual indicator responses.

1. Ecology and Health

Indicator responses show strong engagement with basic ecological practices. A large share of respondents reported efforts to promote conscious energy consumption, to use electrified appliances such as e-vehicles or heating systems, and to install systems on already developed or low-impact land. These were among the more frequently affirmed indicators in this category. By contrast, more demanding or resource-intensive actions—such as investments in green infrastructure or dedicated biodiversity protection measures—were rarely reported. These practices played a lesser role overall and were mostly implemented by a small number of regional ECs.

2. Self-Sufficiency and Supply Security

Approximately 75% of communities indicated that they had defined self-sufficiency targets, reflecting broad strategic awareness. However, implementation of enabling technologies was more limited. Around 40% of respondents reported not using energy storage systems or load-shifting tools, such as energy management software. Other indicators related to grid-supportive Behavior and demand-side flexibility were also fulfilled less frequently. This suggests a gap between ambition and operational capacity.

3. Affordable Energy and Economic Viability

This category featured some of the most widely implemented practices. Over 80% of communities reported offering electricity below market prices, reflecting ECs' non-commercial orientation. However, many noted that this was only possible due to volunteer efforts, raising questions about long-term viability. By contrast, only about one-third of respondents reported specific support mechanisms for low-income households, such as solidarity pricing or electricity donations. This indicates that affordability is generally addressed but not always targeted at social equity.

4. Regional Development

Around half of the ECs reported using local contractors and prioritizing Austrian- or EU-manufactured products. These indicators show moderate engagement with local value creation goals. Fewer communities reported founding new enterprises as part of their EC activities. Additionally, while REGs and LEGs reported relatively active cooperation with other ECs or municipalities, BEGs described more limited access to such networks.

5. Education and Research

Just under half of respondents indicated that they offer or participate in educational activities, such as workshops or internal training. This suggests a moderate level of engagement with community learning. However, only around 35% reported involvement in research collaborations, pointing to limited integration with academic institutions or formal knowledge-sharing processes.

6. Equal Opportunity and Inclusive Processes

Although this category was rated as less important in the self-assessment (see Section 2.4.13), implementation data shows strong attention to transparency, particularly in pricing and decision-making processes. However, some indicators revealed lower engagement. For example, fewer than 30% of respondents reported active efforts in data protection and cybersecurity. Differences between EC types were also apparent: REGs and LEGs more frequently reported user-friendly communication and accessible processes, while BEGs placed less emphasis on these aspects.

7. Community Benefit
This category showed the highest levels of reported fulfilment. Over 93% of respondents stated that participating in an energy community was a meaningful contribution to the energy transition, and more than 91% reported overall satisfaction with their membership. Additionally, over 40% noted a positive impact on their quality of life. These responses point to strong non-material benefits for participants and suggest that many ECs are succeeding in creating personal and social value beyond energy production alone. While the aggregated results illustrate common implementation patterns across the full sample, a more detailed breakdown by community type reveals important differences in how sustainability goals are pursued. These divergences are explored in the next section.

2.4.12 Diverging Practices Across Community Types

To examine differences in engagement by community type, a focused analysis was conducted on indicators with less than 90% agreement across Local Renewable Energy Communities (LEGs), Regional Renewable Energy Communities (REGs), and Citizen Energy Communities (BEGs). The findings show how organizational structure and resource access shape approaches to sustainability goals. For Criterion 2.1, Self-Sufficiency Rate, 100% of BEG respondents expressed satisfaction, compared to about half of REG and LEG respondents. This likely reflects differences in infrastructure and optimization tools; many REGs and LEGs rely on a single generation type (typically PV) and around 40% reported not using storage, load-shifting, or energy management systems.

For Criterion 4.3: Regional Cooperation, REGs and LEGs reported stronger collaboration with neighbouring communities or municipalities. BEGs often cited limited access to such networks; one BEG noted that while collaboration was of interest, participation in regional networks was difficult to implement.

For Criterion 6.3, User-Friendly Procedures, REGs and LEGs emphasized inclusive practices—such as central meeting locations and plain language communication—while BEGs rated these aspects as less relevant or deprioritized them.

A detailed account, including visualizations and commentary, is available in the original German report (Project Report D5). These findings were also discussed during the stakeholder workshop and informed the project’s final recommendations.

2.4.13 Self-Assessment and Reflections

In addition to responding to the indicator-based questions in the national survey (Section 2.4.7), participants were asked at the end of the survey to directly assess the perceived importance of each of the seven overarching sustainability categories for their energy community. This self-assessment was captured using a five-point Likert scale, ranging from 1 (not important) to 5 (very important), and reflects subjective prioritization rather than reported implementation.

The Categories Ecology and Health, Self-Sufficiency and Supply Security, and Affordable Energy and Economic Viability were most frequently rated as highly important. By contrast, the Categories Education and Research and Equal Opportunity and Inclusive Processes received comparatively lower importance ratings, suggesting that these areas are currently viewed as less central by many respondents. This self-assessment complements the earlier analysis of indicator responses, which reflect the extent to which sustainability-related practices are being implemented in practice. Comparing these two perspectives—perceived importance versus reported implementation—can offer valuable insight into potential gaps between strategic priorities and actual activities.

Insights from the survey responses and stakeholder workshop enabled the identification of both strengths and persistent challenges in the development of energy communities—including areas where conflicting objectives or structural barriers may arise. Building on this analysis, a set of targeted recommendations was developed to support decision-makers, support institutions, and other relevant actors in strengthening the enabling environment for energy communities.

Media recognition and visibility of energy community diversity: Different types of energy communities (ECs) offer flexible organizational models with varied goals and structures. Clear media coverage and public recognition of this diversity are essential to improve understanding, increase acceptance, and support appropriate policy frameworks.

Recognition of voluntary engagement: Voluntary work is central to EC success. Public recognition—through events, media, or awards—can help motivate and retain volunteers while raising awareness of community contributions to the energy transition.

Standardizing evaluation criteria and indicators: Further development and standardization of assessment tools are needed to evaluate ECs effectively, including metrics for regional value creation and environmental impact. Standardized tools support evidence-based decisions at operational and strategic levels.

Information and exchange platforms: Centralized platforms should provide practical guidance, data, and evaluation methods, while enabling networking and shared learning. Such platforms support collaborative projects and informed decision-making.

Dialogue forum for regulatory adaptation: A regular exchange among ECs, authorities, grid operators, and other stakeholders can align legal frameworks with evolving technical and organizational needs, while clarifying roles and responsibilities.

Participatory design of digital tools: ECs should be actively involved in the design of digital tools (e.g., billing systems, data platforms) to ensure these systems reflect real-world needs and practices.

Support services for disadvantaged individuals: Anonymous, low-threshold advisory services are needed to assist those affected by energy poverty or social disadvantage in accessing ECs and related support programs.

Research to reduce complexity: Targeted research should focus on simplifying systems and streamlining processes, such as through frugal innovations. This helps ease implementation and reduces the burden on volunteers.

Pilot projects for inclusive models: Pilot initiatives should test new pricing, investment, or governance models—particularly those that promote inclusion, such as greater participation by underrepresented groups. These projects can serve as models for broader adoption.

Awareness-raising initiatives: Campaigns should inform the public about ECs, renewable energy, blackout preparedness, data protection, and the circular economy—empowering informed participation in the energy transition.

Targeted financial support: Start-up funding and financial aid for educational and outreach activities are essential to support new ECs and strengthen their visibility, capacity, and long-term impact.

Based on defined criteria and indicators, ECs can evaluate their contributions to sustainable development and identify areas for improvement. The analysis revealed goal conflicts and problem areas, leading to actionable recommendations and laying the groundwork for standardized assessment tools. Comparing EC types highlighted structural trends and potential research questions.

The evaluation shows both progress and complexity in Austria's EC sector. Communities perform well in areas like affordable energy and member satisfaction but face challenges in education, inclusion, and technical capacity. Results vary by community type and governance model, reflecting the sector's diversity.

Compared to earlier-stage ECs described in Section 2.1 for Work Package 2, those in this evaluation show greater organizational maturity and ambition—likely due to accumulated experience and natural sector development. Many participants from Work Package 5 were board members or founders, while those in Work Package 2 were mainly members with limited operational roles. Together, the findings reflect a dynamic, evolving field shaped by policy, digital tools, and changing user expectations.

2.5 Work Package 6: Field Test Implementation and Monitoring

Work Package 6 focused on the implementation, operation, and evaluation of energy communities in real-world settings. The aim was to explore how local energy production could be better used and shared within and between communities—enhancing self-consumption, enabling member-to-member exchange, and assessing whether linking multiple communities could increase flexibility and efficiency.

Tech-Communities (testbeds) were established in households, apartments, municipal buildings, and commercial sites. These testbeds used hardware and digital tools developed or adapted by project partners, including platforms for energy optimization and monitoring. The testbeds allowed examination of how technical and social setups affect coordination under varying local conditions.

Baseline-Communities, in contrast, used simpler models based on existing PV and battery systems, standard self-sufficiency algorithms, and smart meter data for billing. With minimal technical intervention, they served as reference cases for comparing the added value of more advanced configurations.

All communities were monitored for several months to two years, enabling detailed analysis of energy flows, user behavior, and coordination strategies. In some cases, the project also explored linking communities to support broader energy exchange and system-level efficiency.

2.5.1 Selection Criteria for Testbeds

To ensure representative results for the UCERS project, testbeds were strategically selected to reflect a diverse cross-section of energy consumption and production environments in Austria. This aimed to capture a wide range of technical, social, and economic factors affecting the implementation of energy communities. The selected sites include public and commercial buildings, single-family homes, and apartment complexes, enabling evaluation under varied operational conditions, user behaviors, and infrastructure settings. Testbeds were chosen for their relevance to key project partners and their potential to illustrate different configurations of renewable energy technologies such as photovoltaic (PV) systems, battery storage, electric vehicles (EVs), and heat pumps. These are listed in Table II.

The selection balanced building types and participant profiles—including homes, apartments, and business sites—to explore diverse real-world energy community models. Practical considerations, such as existing infrastructure, technical readiness, and participant engagement, also shaped the final selection. While not exhaustive, the chosen testbeds offer a varied sample relevant to the Austrian context. The selected sites are described in Table II.

Table II: Description of Testbeds Available to Project UCERS (FHTW).

Project Partner(s)	**Nr. of Testbeds**	**Nr. of Dwellings**	**Description**
neoom:	7	7 Buildings in 2 ECs	Public and Commercial Buildings with PV and Battery Systems
Reisenbauer Solutions GmbH &Energy-Climate GmbH:	1	7 Households 1 EC	Single-Family Homes with PV, Battery, EVs, and Heat Pumps
Spitzer GmbH:	1	3 Buildings 1 EC	Commercial Buildings with EV Integration
Fronius International GmbH:	1	7 Apartments 1 EC	Apartment Building with PV System

2.5.2 neoom: Public and Commercial Buildings with PV and Battery

The neoom testbeds involved public and commercial buildings with photovoltaic (PV) systems and battery storage, suited to high daytime energy use and enabling increased self-consumption, self-sufficiency, and flexibility. Existing systems were used, with project efforts focused on integration, data collection, and coordination. PV sizes ranged from 25 to 260 kWp, paired with lithium iron phosphate batteries (approx. 20 kWh capacity, 10 kW power).

Energy management was supported by neoom’s hardware and digital tools. The BEAAM IoE Gateway linked inverters, batteries, and meters; the CONNECT platform enabled real-time optimization; and the KLUUB platform aggregated data, supported forecasting, and facilitated user engagement via the neoom App. These tools were adapted and further developed under the Community Operation & Optimization Platform (COOP). Their deployment across testbeds validated COOP’s modular approach to managing decentralized energy systems, enhancing efficiency, transparency, and shared self-consumption.

2.5.3 RSO/ENC: Single-Family Homes, PV, Battery, EVs, & Heat Pumps

The Reisenbauer/Energy-Climate (RSO/ENC) testbed involved single-family homes with various combinations of photovoltaic (PV) systems, battery storage, electric vehicles (EVs), and heat pumps—technologies increasingly common in Austrian households. With varying energy demand and technology adoption, the testbed offered insights into decentralized production, household-level coordination, and local energy resilience. Existing systems were used, with project activities focused on integration, data collection, and coordination. PV sizes ranged from 800 W to 16 kWp, and two homes included batteries (20–30 kWh). Reisenbauer installed energy meters and monitoring interfaces using wired and wireless protocols, unifying data streams to support self-consumption, flexible load identification, and energy sharing potential. The systems developed contributed to the Community Operation & Optimization Platform (COOP), highlighting flexible, interoperable solutions for distributed residential contexts and enabling responsive, community-level coordination

2.5.4 Spitzer: Commercial Buildings with EV Integration

The Spitzer testbed focused on commercial buildings integrating electric vehicle (EV) charging into broader energy systems, exploring how such sites can manage charging demand and contribute to energy communities through flexible load management and services like public EV charging. While technical implementation was limited by grid constraints and equipment lead times, the testbed supported strategic planning for a commercial energy community, including assessments of site readiness—such as Urkraft Arena (144 kWp PV), DREI Tannen Bad (consumer-only), and Impulszentrum Vorau (59 kWp PV)—as well as the development of cost-sharing models, governance structures, and membership frameworks. These efforts laid the groundwork for future deployment of scalable, community-based commercial energy systems.

2.5.5 Fronius: Apartment Building with PV System

The Fronius testbed involved a multi-family apartment building with a shared 30 kWp photovoltaic (PV) system, highlighting the technical, legal, and organizational complexities of renewable energy in multi-tenant settings. The project focused on collective generation, energy distribution, billing models, and user engagement within a cooperative framework. The PV system supplied both private apartments and common areas, with energy flows managed across eight metering points. It was financed and implemented by the apartment owners, supported by the project team in planning, equipment procurement, funding applications, and community formation—demonstrating a self-organized, community-driven approach. Monitoring relied on existing smart meters and the Austrian Energy Data Exchange (EDA), with the PV manufacturer's app providing real-time performance data to support both operational oversight and resident involvement. The testbed demonstrated how a simple technical setup, combined with collaborative organization, can enable effective community-based renewable energy in apartment buildings.

2.5.6 Monitoring and Analysis Methods

2.5.7 Metrics and Obtaining Measurements

The UCERS project implemented a comprehensive monitoring strategy to evaluate both the technical and social aspects of energy community performance. This dual approach ensured a holistic understanding of how the energy systems operated and how community members interacted with and perceived the energy solutions. The monitoring framework was designed to capture detailed quantitative data on energy performance and qualitative insights into user engagement and satisfaction.

2.5.7.1 Technical Monitoring

Technical monitoring focused on assessing the performance of the energy systems deployed across the testbeds. The key aspects monitored included energy consumption, production, storage, load balancing, and optimization outcomes.

The following metrics were continuously tracked to evaluate the energy community systems:

- **Energy Production:** Data on energy generated primarily from photovoltaic (PV) systems across the testbeds.
- **Energy Storage:** Monitoring of battery charge/discharge cycles.
- **Energy Consumption:** Measurement of the total energy used by individual households, public buildings, and commercial facilities.
- **Load Balancing:** Analysis of how energy loads were distributed across the community to examine usage and investigate reductions in peak demand.
- **Optimization Performance:** Evaluation of self-consumption rates, degree of self-sufficiency, and the effectiveness of demand-side management strategies.

2.5.8 Data Preparation and Validation Approach

To capture accurate and relevant data, different measurement intervals were applied:

- **Long-Term Monitoring:** For datasets spanning multiple years, a 15-minute measurement interval was used to manage large volumes of data while still capturing meaningful trends.
- **Short-Term Monitoring:** For focused studies over shorter periods (weeks to a few months), measurement intervals were reduced to 1–5 minutes to capture more granular energy usage patterns and system behaviors.

Power and energy values were appropriately standardized and translated between different monitoring systems to ensure consistency and comparability across datasets.

To ensure reliable scenario analysis, testbed measurement data underwent a structured, multi-step validation and preparation process to produce a consistent, accurate dataset for comparing different energy community configurations. An automated workflow handled plausibility checks, missing values, and corrections for implausible data (e.g., negative consumption). Specific methods were used to complete battery and PV data, remove outliers, and estimate missing grid values using logical rules and historical data, ensuring consistency across PV production, battery storage, grid exchange, and consumption. This was particularly important for testbeds with high-resolution monitoring, where data quality directly affected analysis outcomes. The final dataset supported robust simulations and calculation of key indicators such as self-sufficiency and self-consumption ratios.

2.5.9 Community Scenario Analysis

2.5.9.1 Definitions of Community Scenarios

Energy data provided by project partners was processed to allow for structured comparison within defined analytical scenarios. Scenarios were developed to examine how energy performance might vary under different forms of energy community organization. These included:

- **Scenario 0 - Baseline**, **individual operation**: Each building or household operates independently, without community coordination.
- **Scenario 1 - Two separate communities**: Participants are grouped into two distinct local or regional energy communities.
- **Scenario 2 - Unified community**: All participants within a testbed are integrated into a single energy community.
- **Scenario 3 - Additional consumer**: A variation in which one participant with high consumption but limited or no generation is included, reflecting situations where energy communities consist primarily of prosumers and may benefit from internal load balancing through additional demand.

Each testbed was evaluated for its impact on local self-sufficiency and participant cost savings. Simulation parameters were tailored to each testbed's characteristics—such as participant number and infrastructure—to reflect practical conditions. Scenarios were applied within testbed groupings (e.g., neoom, RSO/ENC), aligning with the project's focus on realistic, local or regional energy communities. While combining all testbeds into a single community is technically feasible, this cross-regional setup (aligned with a BEG model) was not the main focus.

For the neoom testbed, Scenarios 0–4 were used. Buildings T1–T5 formed EC1; T6–T7 formed EC2 (Scenario 1). Scenario 2 combined all seven buildings. Scenario 3 modified EC1 by simulating building T2 as a consumer-only site (removing its generation and storage). All scenarios were assessed using both static and dynamic allocation methods.

For the RSO/ENC testbed, Scenarios 1 and 3 were excluded—Scenario 1 was not applicable due to its already unified setup, and Scenario 3 lacked sufficient data. Results for EC2 (T6–T7), Scenario 2 (combined EC1 and EC2), and RSO/ENC are omitted for brevity but are included in the full Monitoring Evaluation Report (D6) and available on request.

2.5.9.2 Static and Dynamic Allocation Methods

The analysis distinguishes between two energy allocation methods commonly used in Austrian energy communities: static and dynamic allocation. These determine how locally generated renewable energy is distributed among members for billing purposes. In static allocation, fixed percentages are assigned to each participant based on prior agreements and remain fixed, regardless of actual consumption. Unused energy is sold outside the community. Dynamic allocation, by contrast, is based on real-time consumption within each 15-minute settlement interval. Energy is distributed proportionally according to each member's share of total community consumption during that interval, as defined by Austrian regulations.

This method allows a larger portion of local generation to be allocated within the community, reducing energy sold at lower feed-in tariffs and increasing the share settled at internal rates. Though physical energy flows are unchanged, dynamic allocation can improve participants' economic outcomes by aligning billing more closely with actual usage.

2.5.10 Economic Assumptions and Cost Evaluation

An important component of the analysis involved assessing the economic implications of participating in an energy community. The aim was to estimate annual energy costs and potential savings for different configurations and to present the results in a clear, comparative format. The economic assumptions used in the analysis are outlined below and reflect energy pricing relevant to the study period (2023–2024); it should be noted that energy prices varied across Austria during this time.

- Cost and benefit comparisons were made by evaluating the total energy-related expenses and revenues in each scenario.
- Revenues were based on compensation for surplus electricity fed into the public grid (e.g., €0.09 per kWh for PV exports).
- Expenses reflected the full cost of purchasing electricity from the grid (e.g. €0.36 per kWh for imports), energy costs, cost of grid usage and relevant taxes.

2.5.11 Results of Tech-Communities

This section highlights key findings, focusing on self-sufficiency and economic outcomes as central to assessing the viability of different energy community configurations. While results show promising trends, they should be interpreted with consideration of data and testbed limitations. A full account of all monitored metrics and secondary results is available in the Monitoring Evaluation Report (D6) upon request.

These results should be interpreted with caution, as they are largely based on neoom's Tech-community testbeds—commercial buildings with high PV-to-load ratios and few participants—offering limited insight into more balanced or residential contexts. All sites used only PV, excluding technologies like wind or hydro that affect performance differently. The study also focused solely on electricity sharing. Household data from RSO/ENC communities were insufficient for firm conclusions, underscoring that advanced features like flexible allocation are currently more feasible in smaller, over-producing communities, though broader inclusion remains a key goal. The Fronius Baseline-Community testbed, despite minimal hardware, demonstrated that well-configured, low-complexity setups can still achieve strong energy and economic outcomes.

2.5.11.1 Improvements in Self-Sufficiency

Test data from the neoom testbed (EC1) showed that forming energy communities improved building-level self-sufficiency. Figure 9 compares individual operation (Scenario 0) with community operation (Scenario 1) using both static and dynamic allocation. Under static allocation, gains were minimal due to fixed distribution rules offering little advantage in systems already producing more than they consume. Dynamic allocation led to moderate improvements (+1 to +5 percentage points), as time-based matching of generation and consumption allowed more efficient energy sharing. However, high PV-to-demand ratios across the testbeds meant most buildings already had high self-sufficiency individually, limiting the additional benefits of community integration.

Stronger effects were observed in Scenario 3, where participant T2 was modeled as a non-producer. Without its own PV system, T2's self-sufficiency rose from 0% to nearly 30% through community participation alone (Figure 10). This level, comparable to that of a typical standalone PV system without storage, was achieved without added hardware—highlighting the value of including consumer-only members in producer-heavy communities. Such configurations offer a low-barrier strategy to enhance both individual and collective outcomes within energy communities.

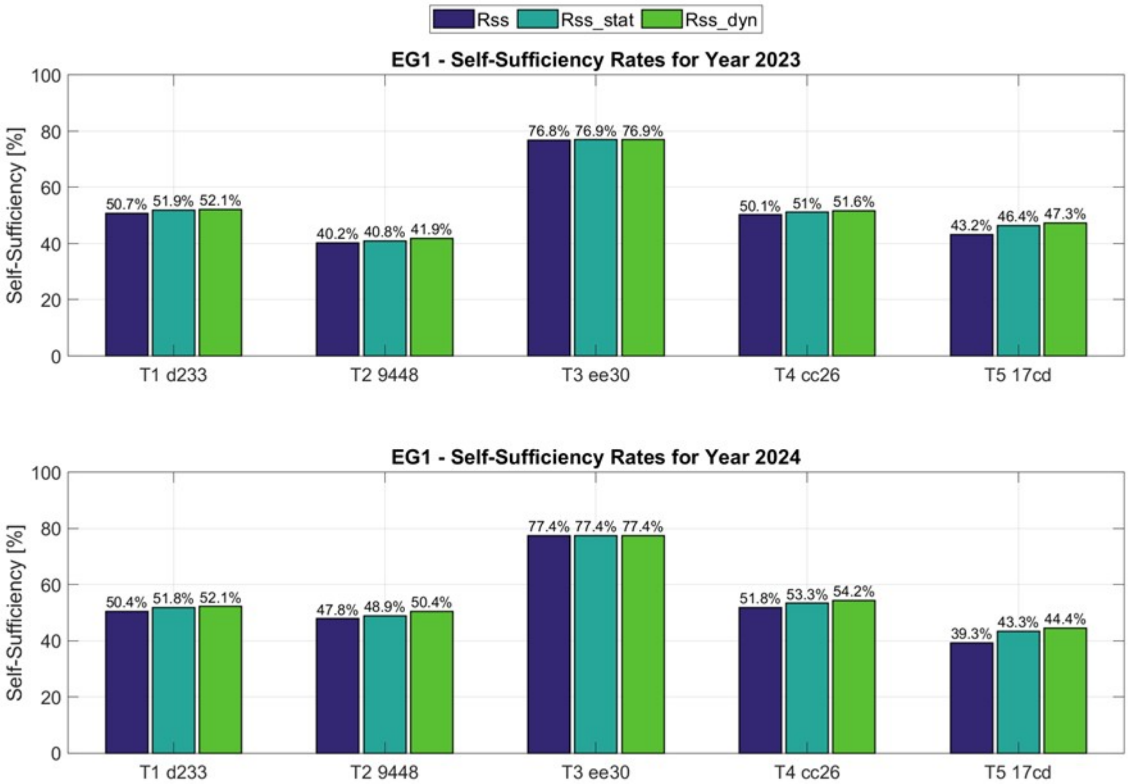

Figure 9: Self-Sufficiency Scenario 1 (T1–T5 as Prosumers) – Self-sufficiency rates (2023–2024) for Scenario 0 and Scenario 1 in Energy Community 1 (EC1), neoom testbed (T1–T5), where all buildings are configured as prosumers (FHTW).

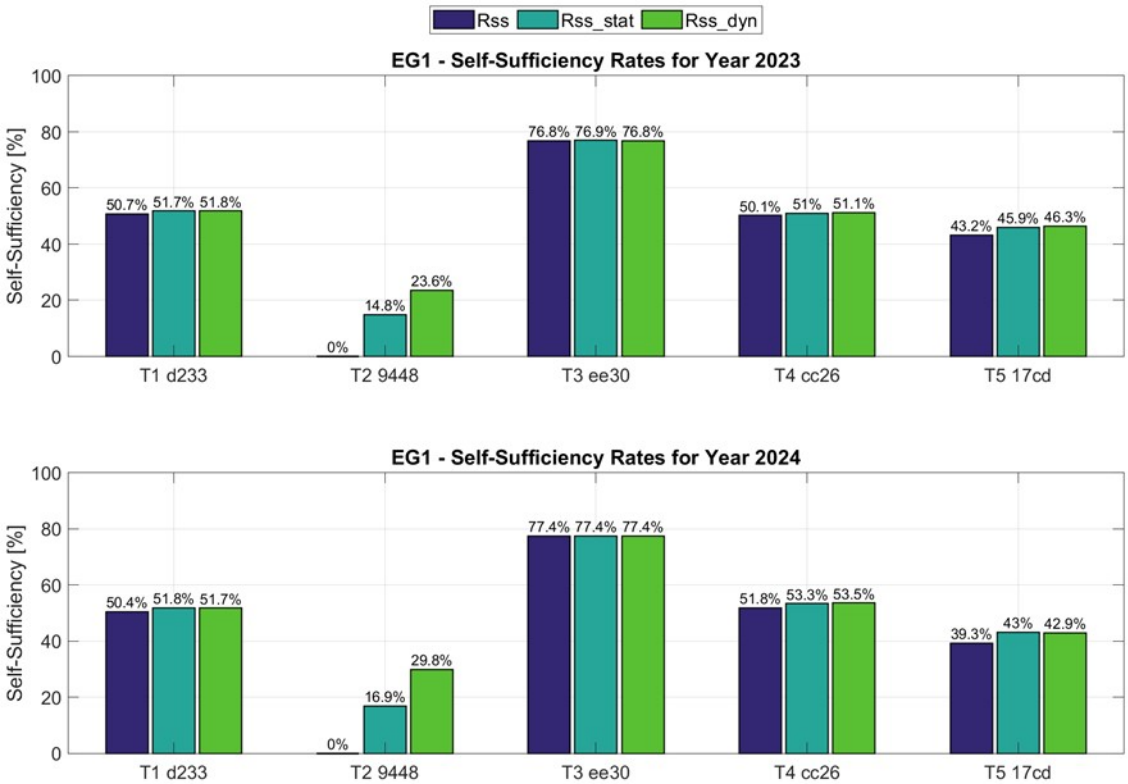

Figure 10: Self-Sufficiency Scenario 3 (T2 as Consumer) – Self-sufficiency rates (2023–2024) for Scenario 0 and Scenario 3 in Energy Community 1 (EC1), neoom testbed (T1–T5), with T2 modeled as a consumer (no PV or storage). Scenario 0 reflects individual operation (T2 operating independently, labeled Rss)(FHTW).

2.5.11.2 Static vs. Dynamic Energy Allocation Methods

The results highlight clear differences between static and dynamic allocation in real-world energy communities. Static allocation offered only marginal self-sufficiency gains in producer-heavy setups due to limited redistribution flexibility. In contrast, dynamic allocation better aligned shared energy with real-time consumption, yielding more substantial improvements. This was evident in Scenario 3, where participant T2, modeled as a consumer-only member, achieved 29.8% self-sufficiency under dynamic allocation versus 16.9% with static (Figure 10). This case illustrates the value of including non-producers in producer-heavy communities, enabling performance gains without additional hardware.

However, while dynamic allocation provides technical and economic benefits, it introduces governance challenges. In individually owned systems, it is relatively straightforward, but in co-owned setups, fairness concerns may arise if energy distribution favors those with higher or better-timed consumption. In such cases, static allocation may be preferred for its perceived equity, despite lower efficiency. Thus, allocation strategies should consider both performance and social acceptance. Dynamic models hold promise but require suitable governance, clear communication, and stakeholder involvement to ensure broad support and successful implementation.

2.5.11.3 Economic Impacts

Financial outcomes varied across testbeds, with the strongest benefits seen in mixed participant setups. Scenario 3, where Testbed T2 was modeled as a consumer-only member, showed how energy community participation can reduce costs for non-generating members while also benefiting producers. Compared to independent operation (Scenario 0), T2 saw notable savings: in 2023, €1,570 (9.04%) under static allocation and €2,503 (14.42%) under dynamic; in 2024, €1,762 (10.31%) and €3,117 (18.23%), respectively (Figure 11). These figures reflect net electricity costs based on consumption and grid tariffs, excluding infrastructure costs.

The results emphasize the economic value of internal redistribution, particularly through dynamic allocation, which more effectively aligns surplus generation with real-time demand. For non-producers like T2, this enables access to lower-cost electricity without new investment. More broadly, the findings underscore the importance of community composition: aligning diverse consumption and production profiles—especially with dynamic allocation—can significantly enhance the financial viability of energy communities and extend benefits to members without their own renewable generation.

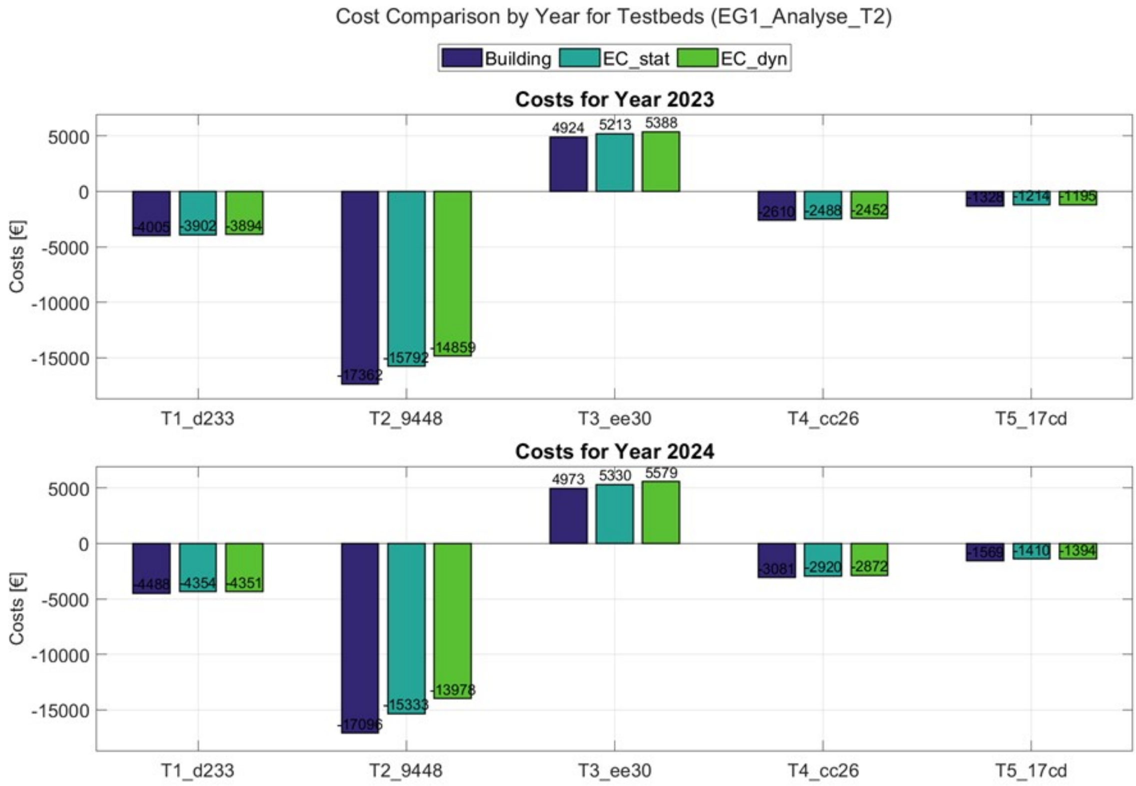

Figure 11: Annual Electricity Costs Scenario 3 (T2 as Consumer) – Annual net electricity costs (2023-2024) for T2 in Scenario 0 (independent operation) and Scenario 3 (community participation) in Energy Community 1 (EC1), neoom testbed (T1–T5). Bars represent Scenario 0 (Building, individual operation) and Scenario 3 using static (EC_stat) and dynamic (EC_dyn) allocation. Positive values indicate net income (more earned than spent), while negative values indicate net electricity costs. Values are based on consumption and applicable energy/grid tariffs, excluding hardware and software investment or depreciation (FHTW).

2.5.12 Results of Baseline-Communities

Unlike the more technology-intensive testbeds, the Baseline-Communities relied on existing PV systems and standard smart meters, with minimal additional infrastructure. These simpler setups enabled energy sharing through administrative processes rather than technical optimization and serve as useful reference cases for understanding the legal, organizational, and functional aspects of early-stage residential energy communities.

This section focuses on a pilot in Upper Austria, where a shared PV system supplied solar energy to a seven-unit residential building, feeding excess electricity into the grid. Although more Baseline-Communities were initially planned, regulatory changes and difficulties in engaging participants limited implementation. Still, the selected site provided valuable operational data and insights into the administrative and legal challenges of shared residential energy systems.

2.5.12.1 Energy Performance and Self-Sufficiency

Over the course of 2024, the PV system achieved an annual self-sufficiency rate of 40%, meaning that 40% of the building's electricity consumption was met directly by solar generation. Seasonal variations were observed, with higher self supply in summer months. A detailed quarterly breakdown is provided in Table III.

This level of self-sufficiency demonstrates the technical viability of shared PV systems in multi-unit dwellings, even in the absence of battery storage. The building also contributed a substantial amount of surplus energy to the grid. The associated financial returns were directed into the building's reserve fund and were broadly equivalent to the income generated by one to two additional rental units. These funds can be used to support ongoing maintenance and infrastructure upgrades, as well as future investments in energy or environmental measures.

Table III: Quarterly Energy Balance (Shared PV System) - Quarterly energy balance for the shared PV system in a multi-unit residential building. Note: the installed PV capacity corresponds to approximately 2 kWp per 1,000 kWh of annual electricity consumption (FHTW).

Period	Production (kWh)	Self-Supply (%)
Q1	3,923	36%
Q2	10,332	56%
Q3	9,766	52%
Q4	2,338	27%
Total 2024	**26,326**	**40%**

2.5.12.2 Organizational Experience and Lessons Learned

Beyond the technical outcomes, the testbeds provided valuable practical experience that informed the development of the Community Digital Energy Platform (CDEP) in Section 2.2 and the cooperative models discussed in Section 2.3. These contributions were shaped by real-world implementation steps, including project planning, internal coordination, and the integration of legal and administrative procedures.

One key area of learning concerned the legal and organizational status of so-called Austrian Wohnungseigentümergemeinschaften (WEGs)—joint ownership associations commonly found in Austrian residential buildings (apartments). Their role in the energy system is not always clearly defined under current legislation, particularly with respect to eligibility for funding and their function as legal contracting parties. While it is understood that WEGs themselves vary in structure and governance, future legislative and support programs may benefit from explicitly addressing their position, in order to streamline participation in renewable energy projects.

Practical challenges also arose in communicating the distribution of benefits among residents, particularly between apartment owners and tenants. Questions of who receives which benefits, under what terms, and how these are financed through the WEG required careful consideration. Additional complexity came from administrative requirements such as obtaining necessary approvals, updating energy sales contracts (typically renewed annually), and navigating ownership structures—especially for the central energy meter to which the PV system is often connected. In many cases, this meter is registered to the WEG but managed by a third party, requiring coordination among multiple stakeholders.

Clearer identification of authorized signatories—both within the WEG and among external entities such as funding bodies, grid operators, and energy retailers—was also identified as an area needing improvement. In some cases, WEG decision-making processes (e.g., general assemblies held only every two years) posed scheduling constraints. These administrative and governance-related lessons offer valuable input for future policy and platform development aimed at increasing the uptake of renewable energy in multi-unit buildings.

2.6 Work Package 7: Assessment, Replication and Scalability

Efforts regarding Work Package 7 are covered in Sections 3 and 4.

3 Results and Conclusions

Over the course of the UCERS project, multiple empirical studies, technical developments, and real-world testbeds were carried out to better understand how Austrian citizens engage with energy communities (EC), how these communities perform in practice, and what conditions support their long-term contribution to sustainability goals. This section synthesizes findings from the project's major components, including two large-scale key surveys, the development and testing of digital platforms, and a set of real-world testbeds. Together, these efforts offer a multi-dimensional view of the opportunities and challenges that characterize the emerging EC sector in Austria.

3.1 Early-Stage Participation and Emerging Expectations

The first major survey, conducted early in the project (Q4, 2023 – Q1, 2024) in collaboration with the digital service provider neoom, focused on participants from a set of newly established ECs. These communities were among the first to be implemented under Austria's revised energy legislation and offer a snapshot of how early adopters encountered and interpreted the EC model. Of the 174 respondents, most were electricity consumers (approximately 75%), with the remainder identifying as prosumers. Demographically, the group consisted predominantly of male participants from rural or semi-rural areas, with relatively high levels of income and education.

Financial motivations were the most frequently cited reason for joining, but many respondents reported that these anticipated benefits had not yet been realized. This outcome should be interpreted in the context of early-stage rollout: Austria's smart metering infrastructure and backend billing systems were still in development, limiting the technical capacity of ECs to fully implement energy-sharing and transparent billing processes. As such, these findings reflect both the high expectations that accompanied EC membership and the systemic limitations that initially constrained delivery.

Despite these hurdles, some participants found unexpected value in the form of increased regional identity, energy awareness, and low-threshold engagement opportunities. However, social cohesion within these early communities remained limited. Interview data emphasized that stronger interpersonal ties and local initiative were more often associated with bottom-up models than with top-down, provider-led implementations. Across the board, participants expressed interest in clearer communication, more opportunities for informal involvement, and better tools to help align expectations with operational realities.

3.2 Strategic Development and Mature Practices

The second major survey was conducted later in between Q3 and Q4 of 2024 and formed the basis of a structured sustainability evaluation (Section 2.1). This nationwide effort reached 59 respondents from 55 ECs, spanning LEGs, REGs and BEGs. These later-stage communities reflected more varied organizational models, many of them driven by citizen initiative and characterized by stronger local governance structures.

Using an evaluation scheme of 22 sustainability criteria organized into seven categories, this survey assessed both implementation practices and perceived importance. High fulfilment levels were observed in Categories 3: Affordable Energy and Economic Viability and 7: Community Benefit—over 80% of ECs provided electricity below market prices, and more than 90% of respondents felt their participation was meaningful. At the same time, gaps emerged in categories like 6. Equal Opportunity and Inclusive Processes, where actual implementation lagged behind perceived importance for certain criteria.

Radar charts helped visualize these discrepancies, providing participating ECs with tools for internal reflection and planning. Analysis by EC type revealed structural distinctions: BEGs, for instance, reported stronger satisfaction with self-sufficiency efforts, while LEGs and REGs tended to score higher on regional collaboration and inclusivity.

3.3 Comparative Insights and Sector Evolution

Although the two surveys differed in timing, scope, and methodology, their results are complementary. The early neoom-supported ECs played a foundational role in testing legal and technical frameworks during a period when Austria's national infrastructure—particularly the Austrian Energy Data Exchange Platform (EDA)—was still maturing and rolling out new features. neoom's experiences highlight the challenges of onboarding users under these limitations, while also demonstrating how pre-structured services facilitated initial adoption.

Later communities were shaped by greater operational flexibility, often driven by community members themselves and guided by broader sustainability goals. These ECs had more time to develop internal governance structures and align their operations with local values and strategic ambitions. As such, they offer a forward-looking perspective on what energy communities can become as technical systems and support mechanisms mature.

Together, these findings illustrate a clear developmental trajectory in the Austrian EC landscape—from early implementation and expectation management to more holistic models of community empowerment and sustainability planning. This progression underscores the importance of supporting diverse EC models through adaptable policies, user-centered tools, and capacity-building resources.

3.4 Digital Infrastructure: User Engagement & Optimization

To support this evolution, the UCERS project developed a suite of digital tools designed to facilitate every stage of EC engagement—from initiation to operation. Two primary platforms were created: the Community Data Exchange Platform (CDEP) and the Community Operation & Optimization Platform (COOP). CDEP provided a user-friendly entry point for potential members and administrators, integrating onboarding tools, project directories, administrative modules, and secure links to EDA. COOP focused on operational efficiency, offering features such as local energy forecasting, device control, automated billing, and member dashboards.

These tools were shaped through continuous user testing and refinement in project testbeds. The integration of real-time data and user feedback allowed for responsive adjustments and demonstrated tangible gains in transparency, operational efficiency, and energy optimization. Machine learning models for consumption forecasting and coordinated storage management showed potential to significantly enhance both self-sufficiency and individual cost savings.

3.5 Testbeds: Real-World Performance and Lessons

To validate the platforms and assess real-world energy community performance under diverse conditions, the UCERS project implemented a set of testbeds encompassing both technically advanced Tech-Communities and more basic Baseline-Communities. These settings enabled close monitoring of performance under varying technological, regulatory, and user conditions.

In Tech-Communities, the use of dynamic energy distribution—enabled by smart controls, batteries, and demand management—led to measurable improvements in self-sufficiency and financial returns. Particularly noteworthy were gains achieved simply by optimizing community composition: for example, introducing consumer-only members into producer-heavy communities yielded strong results even without additional hardware.

Baseline-Communities—such as multi-apartment residential sites with shared PV—demonstrated that significant self-sufficiency and financial benefits are also possible under simpler conditions. In one case, a housing complex achieved 40% self-sufficiency with minimal investment, although legal and organizational barriers (especially related to Wohnungseigentümergemeinschaften, or joint ownership associations) posed notable challenges. However, while self-consumption was relatively high, the potential to support the broader electricity system—through flexibility or grid services—remained limited compared to the more technically advanced configurations implemented in the Tech-Communities. These testbed findings confirm that energy communities can function effectively across diverse contexts but also highlight the need for supportive legal, organizational, and digital frameworks to maximize their potential.

Overall, the UCERS project reveals a sector in active transition—moving from early pilot implementations shaped by infrastructure constraints to more community-driven models focused on sustainability and inclusion. Across testbeds, surveys, and digital development, a consistent theme emerged: successful energy communities require both reliable technical systems and strong social foundations.

4 Outlook and Recommendations

The UCERS project examined the key phases of EC development—from early onboarding to mature operation—across multiple settings, methods, and technologies. These recommendations synthesize that learning into practical guidance for policymakers, support institutions, and EC practitioners.
Key themes include broadening participation, strengthening governance, aligning technical and social systems, and expanding the digital backbone for scalable, citizen-centered ECs. Together, they chart a path toward an inclusive and resilient EC ecosystem, aligned with national and EU-level energy goals.

Toward Inclusive and Sustainable ECs
The UCERS project engaged deeply with Austria's emerging EC landscape, offering a unique opportunity to trace its evolution over time. Insights from early-phase communities supported by structured service models and later, more self-directed ECs evaluated through a national sustainability evaluation scheme (Section 2.4) highlight both the diversity of experiences and the structural shifts occurring across the sector.

Managing Expectations in Early ECs
Early ECs served as crucial pilot cases under Austria's new regulatory framework. While technically and legally pioneering, these communities also revealed the importance of managing participant expectations. To build and maintain trust, ECs should emphasize realistic, transparent onboarding. Clearer communication around benefit timelines and system dependencies can better align motivations with what is feasible in early implementation phases. Support providers have a critical role to play here by offering tailored materials and setting cautious but constructive expectations.

Expanding Access and Inclusion

As the EC sector matured, new communities emerged with stronger grassroots foundations and broader sustainability goals. Still, both early and later-stage ECs showed limited demographic diversity. To broaden access, outreach must be more inclusive, using accessible language and formats that resonate with underrepresented groups, including tenants, younger individuals, and women.
Informal, low-effort engagement activities (e.g., information sessions, light volunteer opportunities) can serve as effective entry points. Moreover, bottom-up ECs consistently demonstrated stronger alignment between member expectations and operational realities—underscoring the value of participatory governance. Involving members in tool design, community rules, and planning processes is vital for building trust and resilience as ECs take on more complex roles in the energy system.

Aligning ECs with Systemic Sustainability Goals

Sustainability evaluation revealed tensions between affordability, autonomy, and ecological responsibility. For instance, communities relying heavily on volunteerism may face long-term viability risks, while unbalanced PV systems without storage can compromise grid stability. Renewable expansion, if not carefully managed, may also generate negative environmental impacts. Addressing these tensions calls for flexible, context-sensitive governance and support tools. These may include demand-responsive sizing, shared storage investments, differentiated tariff models, and solidarity pricing mechanisms. Pilot projects that test inclusive models—with explicit attention to supporting vulnerable households—can provide both practical guidance and political momentum.

Scaling Digital Tools for ECs

UCERS demonstrated how thoughtfully designed digital tools can aid EC operation. The Community Data Exchange Platform (CDEP) and Community Operation & Optimization Platform (COOP) aided in supporting administrative processes, facilitating onboarding, and enabling real-time monitoring and coordination. Recommendations include continued investment in modular, user-oriented systems that integrate well with national platforms like EDA and evolve with EU-level data requirements. Forecasting tools, storage coordination features, and dynamic dashboards should be expanded and supported with user training.

Machine learning models for consumption forecasting also show promise, especially when paired with time-based pricing schemes. However, these tools require reliable data, user trust, and transparent communication about limitations. A strong emphasis on privacy-respecting, lightweight data architecture will be key to broad adoption. Simulation results affirm the value of incentive-based internal tariffs and coordinated battery use to optimize intra-community exchange and cost savings. Transparent cost structures, enabled by digital interfaces, can foster trust and informed decision-making—laying the groundwork for behavioural change and long-term engagement.

To accelerate progress, national policy should promote pilot projects that combine digital innovation with participatory governance. Regulatory frameworks must reduce administrative complexity, encourage open standards, and reward grid-supportive behaviours. Research funding should prioritize predictive control, decentralized optimization, and cross-sectoral energy integration.

Smart Design and Inclusive Participation

UCERS testbeds illustrated the real-world potential of ECs in both technically advanced and low-complexity contexts. Key findings point toward several design and policy directions for enabling broader uptake. Dynamic allocation demonstrated improved self-consumption and cost-efficiency, particularly for consumer-only members. To leverage this potential, future support programs should encourage thoughtful community composition—balancing generators and consumers to optimize resource use without requiring extensive infrastructure.

Equity and governance remain central. In co-ownership or joint ownership models (e.g., Wohnungseigentümergemeinschaften), regulatory ambiguity and perceived fairness can pose barriers. Transparent rules, simulation tools to visualize trade-offs, and inclusive decision-making processes are essential for navigating these tensions.

Simpler ECs also offer promise. One residential testbed reached 40% self-sufficiency using only PV and smart meters, showing that entry-level ECs can deliver substantial benefits. Policymakers should consider support schemes that lower the bar for entry—particularly for less digitally experienced or resource-constrained communities.

Finally, many implementation barriers were social rather than technical. Tailored outreach, flexible membership models, and advisory services for diverse user profiles (e.g., tenants, elderly residents) are needed to make ECs broadly accessible. Building this social infrastructure is just as important as investing in physical systems.

Final Reflections

The UCERS project shows that energy communities in Austria are not only technically feasible—they are socially valuable, strategically relevant, and essential to a resilient energy transition. The recommendations above are not standalone interventions but interlocking enablers: participatory governance complements digital infrastructure; inclusive outreach supports broader participation; clear policies create room for innovation. As ECs continue to evolve, Austria must support their expansion with the same diversity and adaptability that defines their success. The next phase of this journey will require coordination across institutions, alignment of regulatory tools with community needs, and a shared commitment to equitable energy futures. While the UCERS project focused on electricity, expanding energy community models to include thermal energy remains an important area for future progress. In this area, additional work is still needed—particularly in relation to measurement approaches and supporting infrastructure—to enable comparable levels of integration.

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6 Appendix

Additional reports featuring full results and detailed information on methodologies are available upon request. See contact details below.

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