2025

green energy lab.at

UCERS *Final Report*

Foto: Recoil/Shutterstock

Foto: Manuel Schmid/Shutterstock

This project was part of the Flagship Region Green Energy Lab and supported with the funds from the Austrian Climate and Energy Fund and implemented in the framework of the RTI-initiative "Flagship Region Energy".

klima energie fonds

UCERS

User-Centered Solutions for Digital and Sustainable Energy Communities

UCERS Final Public Report

Project Duration: 01.03.2021 – 28.02.2025

Classification: Public

Version: 1.0 (Final)

Publication Date: 27.05.2025

Prepared for: Austrian Research Promotion Agency (FFG)

Distribution: This document is approved for public release.

Authors:

Matthew Clarke[1], Natalie Taupe[1], Edit Parada[1], Frederike Ettwein[1], Christina Huber[2], Markus Fischer[3], Yi Guo[1], Matthias Malottke[1], Michael Oberhofer[4], Martin Schloffer[4], Peter Illich[2], Rupert Wychera[3], Jacob Wöginger[2], William Markl[5], Markus Plank[6], Tobias Hofer[7], Josef Bauchinger[7], Eszter Gunnarsson[1]

[1] FH Technikum Wien
[2] neoom AG
[3] Energy-Climate GmbH
[4] 4ward Energy Research GmbH
[5] Reisenbauer Solutions GmbH
[6] Spitzer GmbH
[7] Fronius International GmbH

Project "UCERS – User-Centered Solutions for Digital and Sustainable Energy Communities" (FFG number 892267) was funded through the Vorzeigeregion Energie 2019 program.

Document History

Version:	Date:	Released by:	Changes:
1.0	27.05.2025	Matthew Clarke	Initial release, 1st publication

Document Signature

This document has been digitally signed by its issuer, Matthew Clarke, on behalf of the UCERS Project Team, using a qualified electronic signature in accordance with EU eIDAS regulations. Any version lacking this digital signature may have been altered and cannot be verified as authentic.

To verify the authenticity and integrity of this document, please open it in Adobe Acrobat Reader or another compatible PDF viewer that supports digital signature validation.

SIGNATURINFORMATIONEN		
	Unterzeichner	Matthew John Clarke
	Datum/Zeit-UTC	2025-05-27T20:12:20+02:00
	Prüfinformation	Informationen zur Prüfung der elektronischen Signatur finden Sie unter: https://www.signaturpruefung.gv.at
Hinweis	Dieses mit einer qualifizierten elektronischen Signatur versehene Dokument hat gemäß Art. 25 Abs. 2 der Verordnung (EU) Nr. 910/2014 vom 23. Juli 2014 ("eIDAS-VO") die gleiche Rechtswirkung wie ein handschriftlich unterschriebenes Dokument.	

Table of Contents

List of Figures

List of Table

List of Abbreviations

BEG	Bürgerenergiegemeinschaft (Austrian implementation of CEC)
CDEP	Community Data Exchange Platform
CEC	Citizen Energy Community
COOP	Community Operation & Optimization Platform
EC	Energy Community
ECN	Energy-Climate GmbH
EDA	Energy Data Exchange (Austrian Energy Data Exchange Platform)
EEG	Erneuerbare-Energie-Gemeinschaft (Austrian Implementation of REC)
EV	Electric Vehicle
FFG	DE: Österreichische Forschungsförderungsgesellschaft EN: Austrian Research Promotion Agency
FHTW	Fachhochschule Technikum Wien
Fronius	Fronius International GmbH
LEG	Lokale Erneuerbare-Energie-Gemeinschaft Note: Austrian specific subcategory of REC, local, i.e. same electrical transformer
neoom	neoom AG and its subsidiaries
PV	Photovoltaic
REC	Renewable Energy Community
REG	Regionale Erneuerbare-Energie-Gemeinschaft Note: Austrian specific subcategory of REC, regional, i.e. same electrical substation
Reisenbauer	Reisenbauer Solutions GmbH
RSO	Reisenbauer Solutions GmbH
SDG	Sustainable Development Goal
Spitzer	Spitzer GmbH
UCERS	User-Centered Solutions for Digital and Sustainable Energy Communities
WP	Work Package
4ward	4ward Energy Research GmbH

Foreword

This report presents the main findings of the UCERS project in a form intended to be clear, accessible, and relevant for a broad audience. It is designed for readers including policymakers, municipal representatives, researchers, practitioners, and members of the interested public—many of whom are engaging with the topic of energy communities for the first time, or from diverse disciplinary and practical backgrounds.

It offers a structured summary of key results and lessons learned from the implementation and evaluation of energy communities in real-world Austrian settings. The report condenses a large body of technical work and empirical data into a narrative that is readable, evidence-based, and focused on practical insights. Care has been taken throughout to present findings transparently, including important contextual details and limitations that may shape interpretation.

Where more technical or detailed information is required—such as assumptions behind simulation models, monitoring setups, or data validation procedures—these are provided in the appendices or referenced from relevant internal reports and publications. Additional documentation and methodological details can be made available upon request.

This format reflects the project's commitment to both rigor and usability. It is intended to support the continued development of energy communities in Austria and beyond, by contributing empirically grounded insights that can inform policy, planning, and practice.

About This Report

The results presented in this report have been summarized and interpreted to the best of the authors' knowledge at the time of publication. Given the project's duration across a dynamic economic, political, and environmental context, all findings are reported in relation to the specific time periods during which data was collected and analyzed. Efforts have been made to clearly indicate these time frames and to note developments that may influence how results are interpreted.

Artificial intelligence tools were used to support translation, improve spelling and grammar, refine sentence structure, and provide feedback on report organization and readability. All final content was reviewed and approved by one or more members of the authoring team.

Acknowledgements

The UCERS project – User-Centered Solutions for Digital and Sustainable Energy Communities (FFG number 892267) – was funded by the Vorzeigeregion Energie 2019 program through the Austrian Research Promotion Agency (FFG).

The project was conducted by a consortium of partners: Fachhochschule Technikum Wien, neoom AG (via neoom International GmbH), Energy-Climate GmbH, 4ward Energy Research GmbH, Reisenbauer Solutions GmbH, Spitzer GmbH, and Fronius International GmbH. The consortium worked jointly on the adaptation and development of digital tools, the implementation of test environments, and the establishment of methods for evaluating the social, environmental, and operational dimensions of energy communities.

The project team acknowledges the contributions of stakeholders who participated in workshops, testing, and other engagement formats. Their feedback provided valuable input for aligning technical developments with practical needs and for exploring the societal implications of decentralized energy systems. Special thanks are extended to the Mayor of the Energy Community Schnifis for his support during the development and testing of the assessment scheme. His feedback and continued availability contributed meaningfully to the project's implementation. Appreciation is also extended to Patrick Fuchs and Stephan Heidler of the Austrian National Center for Energy Communities (Österreichische Koordinationsstelle für Energiegemeinschaften), as well as to PV Austria, for their significant contributions to addressing practical challenges in the setup and operation of energy communities.

1 Executive Summary

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, the implementation of real-world testbeds across diverse building types and ownership models, the design of participatory and co-creative engagement processes, and the construction of an evaluation scheme to assess EC contributions to ecological, economic, and social sustainability. The project also incorporated comparative and longitudinal analyses to capture the evolving expectations, experiences, and practices within the EC landscape.

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:

Categories for Sustainable Development

1. Ecology and Health
2. Self-Sufficiency and Supply Security
3. Affordable Energy and Economic Viability
4. Regional Development
5. Education and Research
6. Equal Opportunity and Inclusive Processes
7. Community Benefit

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.

In conclusion, 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 Introduction

The introduction of legal frameworks for energy communities (EC) in Austria in 2021 marked a pivotal moment in the country's energy transition. Designed as non-profit entities, Energy Communities offer citizens, municipalities, and organizations the opportunity to collectively produce, share, and utilize renewable energy at the local level. However, the effective implementation of such communities raised a series of practical, technical, and societal questions that required targeted research and development.

The UCERS project, initiated in parallel with this legislative shift, aimed to address these challenges by developing a suite of digital tools, implementing and monitoring real-world test environments, and establishing methods for assessing the broader social and environmental value of Energy communities.

A central element of the project was the design of a Community Data Exchange Platform, building on existing infrastructure within Austria's energy sector. This platform was intended to provide a secure, scalable, and user-friendly solution for data management and exchange among energy community participants. Key design criteria included data protection, interoperability, and usability—essential for enabling practical implementation and future scaling.

In addition, efforts were made to develop tools to support the internal operation and optimization of Energy communities. Two project partners adapted and advanced their respective digital solutions to address core functions such as billing, data analysis, and operational coordination. These tools contributed to more efficient management processes and provided insights into the needs and dynamics of energy communities in practice.

In a dedicated project area referred to as the Citizen Science platform, efforts were undertaken to incorporate citizen perspectives and facilitate stakeholder contributions. These activities included co-creation workshops, prototype testing, and the development of digital engagement tools. The aim was to foster transparency, strengthen trust, and encourage long-term participation from a broad user base—elements that are critical to the success of community-led energy initiatives.

To complement the technical and participatory dimensions, the UCERS project also focused on developing assessment criteria and evaluation methods that account for ecological, social, and macroeconomic factors. An evaluation scheme was designed to support the holistic evaluation of energy communities, enabling a more comprehensive understanding of their sustainability impacts and guiding principles for future implementation.

Overall, the UCERS project made significant progress in developing foundational tools, generating practical insights, and identifying promising directions for the continued advancement of energy communities in Austria. The project focused on electricity, as this was the primary domain supported by Austria's initial legal framework and existing public infrastructure. While heating is an important component of the energy transition and holds future potential for energy communities, its integration—particularly in terms of measurement and data availability—remains less developed. Nevertheless, the results offer a valuable contribution to both current practice and future research in this emerging field.

This report is organized into a series of thematic sections and supporting appendices. Section 1 provides an executive summary that highlights the project's main objectives, methodologies, and key findings. Section 2, presented above, introduces the context, aims, and structure of the UCERS project. Section 3 then examines engagement and participatory approaches, drawing on early empirical work to explore how stakeholders were involved in the initial formation and development of energy communities.

Section 4 presents a detailed socio-environmental evaluation, including the development and application of an evaluation scheme to assess the sustainability performance of energy communities. Section 5 outlines the digital tools developed and adapted within the project to support technical coordination and user interaction. Section 6 documents the implementation of testbeds and summarizes findings from monitored real-world systems. Section 7 distills the project's cross-cutting insights, and Section 8 offers recommendations and future perspectives based on the accumulated evidence.

Four appendices (Appendices A–D, see Section 9) provide supplementary detail for Sections 3 through 6. Together, the main report and appendices offer both an accessible overview and a deeper technical foundation for those seeking to build on the project's work.

Terminology Note: EU and Austrian Energy Community Terms

The EU term Renewable Energy Community (REC) corresponds to the Austrian Erneuerbare-Energie-Gemeinschaft (EEG). In Austria, however, EEGs are further differentiated based on grid topology into two subcategories: Lokale EEG (LEG) and Regionale EEG (REG). These distinctions are relevant for various studies and data sources referenced throughout this report.

Translating LEG and REG into English as "Local Energy Community" (LEC) and "Regional Energy Community" (REC) introduces ambiguity, as "REC" is already established in EU terminology as a general category. To avoid confusion, the original German abbreviations—LEG and REG—are retained in this report.

The EU term Citizen Energy Community (CEC) corresponds to the Austrian Bürgerenergiegemeinschaft (BEG), which has no further subcategories defined under national law.

Accordingly, "REC" and "CEC" are used when referring to the broader EU-level definitions, while "LEG," "REG," and "BEG" are reserved for Austria-specific implementations. Despite efforts to ensure consistent terminology throughout the document, occasional variations may occur due to the diversity of data sources and stakeholder contributions.

Terminology Note: Self-Consumption and Self-Sufficiency

Terms such as self-consumption and self-sufficiency are typically expressed as percentages and may be referred to in this report as rates or ratios. While ratio may be mathematically more precise, these terms are often used interchangeably in the literature. Due to the diversity of data sources, partners, and monitoring frameworks used throughout this project, minor variations in terminology may occur. In this report, rate and ratio can be interpreted as equivalent for the purposes of readability and consistency.

3 Engagement and Participatory Approaches

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 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. A detailed overview of respondent characteristics is provided in Appendix A (see Section 9.1).

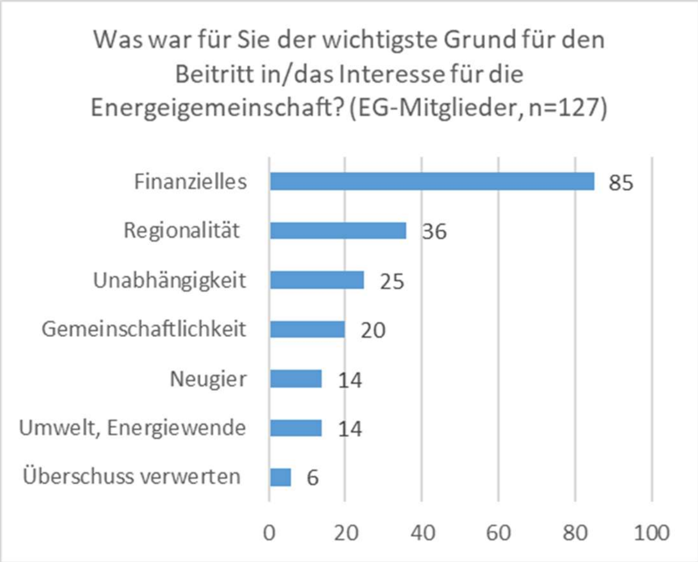

Figure 1: Main Reason for Joining EC - EN Title: What was the main reason for joining or being interested in an energy community? German-terms listed top to bottom: financial, regional, independence, solidarity, curiosity, environmental, sale of excess power (FHTW).

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 significant 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.

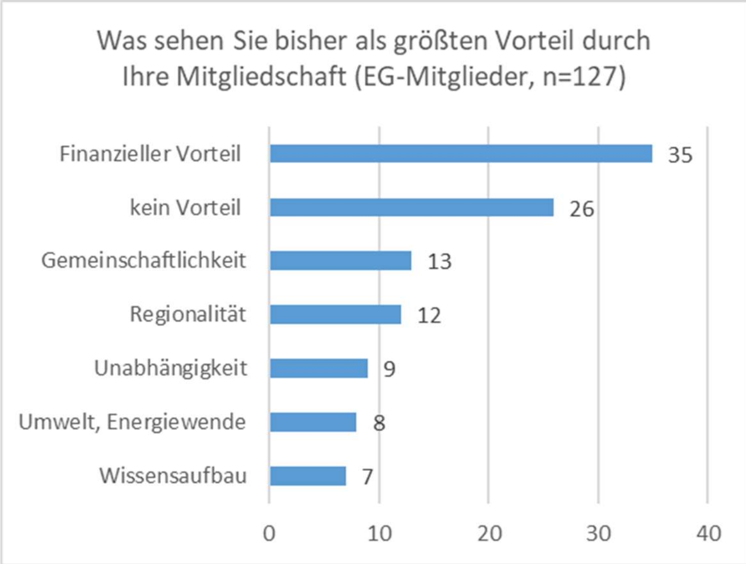

Figure 2: Greatest Benefit of Joining EC - EN Title: What do you consider to be the greatest benefit of joining an energy community? German-terms listed from top to bottom: financial advantage, no advantages, solidarity, regional, independence, environmental, knowledge/experience gained (FHTW).

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 (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.

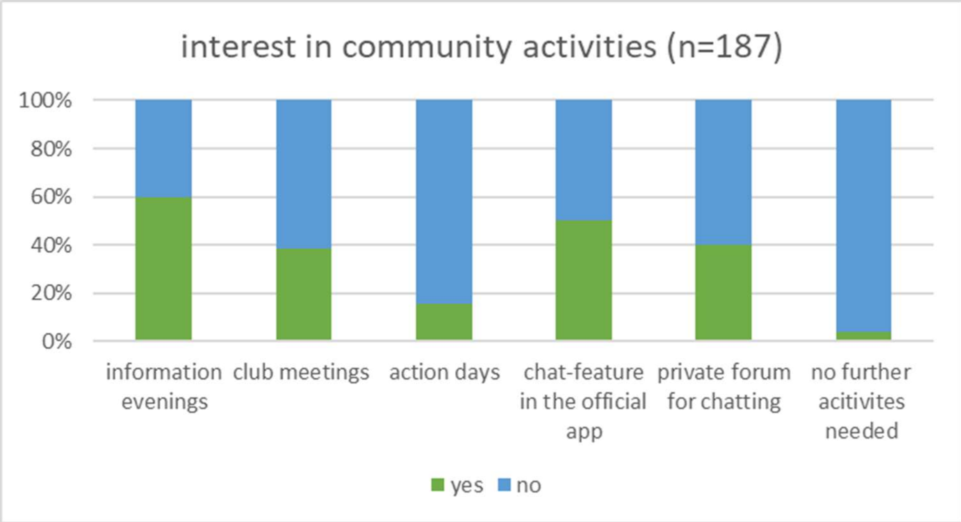

Figure 3: Interest in Community Activities - Interest in community activities of (prospective) EC members (FHTW).

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. Section 5 outlines 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. The next section builds on this foundation by examining a broader range of energy communities, many of which were initiated from the bottom up and assessed using a structured evaluation scheme for assessing sustainability impacts.

4 Socio-Environmental Evaluation of Energy Communities

Building on the early insights presented in Section 3, this section shifts focus to a broader and more mature cross-section of Austria's Energy Communities. Conducted in the third and fourth quarters of 2024, during the later phase of the UCERS project, the study presented here applies a structured sustainability evaluation scheme to assess the extent to which energy communities contribute to social, environmental, and economic goals. While Section 3 emphasized the expectations and experiences of early participants, this section explores how more established communities are aligning their practices with long-term strategic aims.

These communities often feature stronger member-led governance, more diverse goals, and a greater degree of self-organization. Through a combination of surveys, expert input, and stakeholder workshops, the project team developed and tested a comprehensive evaluation scheme to assess their sustainability performance and support future development.

4.1 Sustainable Development

Over the past four decades, the concept of sustainable development has become a central guiding principle in discussions and decision-making processes concerning future developments in politics, economics, science, and civil society (BMEIA, 2024). A widely recognized definition of sustainable development was published in 1987 in the Brundtland Report "Our Common Future" by the United Nations World Commission on Environment and Development (WCED). This definition remains valid and frequently cited today:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland Report, 1987).

The goal of the sustainable development is to shape society and the economy in such a way that the living conditions of the present generation are improved globally, without endangering the prospects of future generations. This requires the preservation of essential social, economic, and natural foundations (Brundtland Report, 1987). Sustainable development thus goes beyond the boundaries of purely scientific analysis and holds fundamental societal and political relevance.

It is also important to recognize that sustainability is not a predefined strategy, but a guiding principle that must be operationalized in order to be effectively implemented (Rogall, 2002). Goals, criteria, and indicators must be defined in order to provide direction in line with sustainable development and to make progress measurable. A prominent example is the United Nations' 17 Sustainable Development Goals (SDGs), adopted in 2015, which are made measurable through so-called targets and indicators (SDGs, 2025).

Criteria (target areas) and indicators (measurable variables) are central elements of sustainability assessment. The way we measure something significantly influences our actions, which is why the selection and application of appropriate sustainability criteria and indicators is of great importance (Günther and Schuh, 2000). However, the selection and application of such criteria is challenging, as it must consider not only scientific requirements but also political and societal values and expectations, which requires a transdisciplinary approach (Jahn, 2021).

4.2 An Integrated Approach to Sustainability

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. These goals and rules are listed in Table I and serve as guiding criteria for this research project.

Table I: Minimum Requirements for Sustainable Development. Adapted and translated from (Grunwald und Kopfmüller, 2022). Originally published in German.

Securing Human Existence	**Preservation of Societal Productive Potential**	**Safeguarding Development and Action Opportunities**
Protection of human health	Sustainable use of renewable resources	Equal opportunities in education, employment, and access to information
Ensuring basic needs	Sustainable use of non-renewable resources	Participation in societal decision-making processes
Independent livelihood	Sustainable use of the environment as a sink	Preservation of cultural heritage and cultural diversity
Fair distribution of environmental usage opportunities	Avoidance of unacceptable technological risks	Preservation of the cultural function of nature
Compensation for extreme income and wealth disparities	Sustainable development of physical, human, and knowledge capital	Conservation of social resources

4.3 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 up 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.

4.4 Methodology

Building on the conceptual foundation outlined in Sections 4.1-4.3, this section presents the methodology used to develop and apply an evaluation scheme for the assessment of energy communities as well as its application. 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 4.4.4) 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% fulfillment 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 4.4.6).

The evaluation scheme was developed through an iterative, participatory process, summarized in Figure 4. 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 and is described in detail in Sections 4.1-4.3.
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.

Each of these steps is described in greater detail in the following sections.

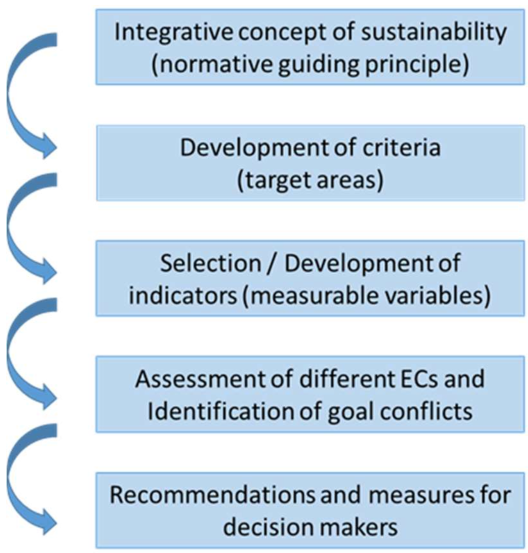

Figure 4: Methodological steps for Work Package 5 (FHTW).

4.4.1 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. The guiding principles used in the development of the criteria are shown in Table I, and the methodological approach is visualized in Figure 5.

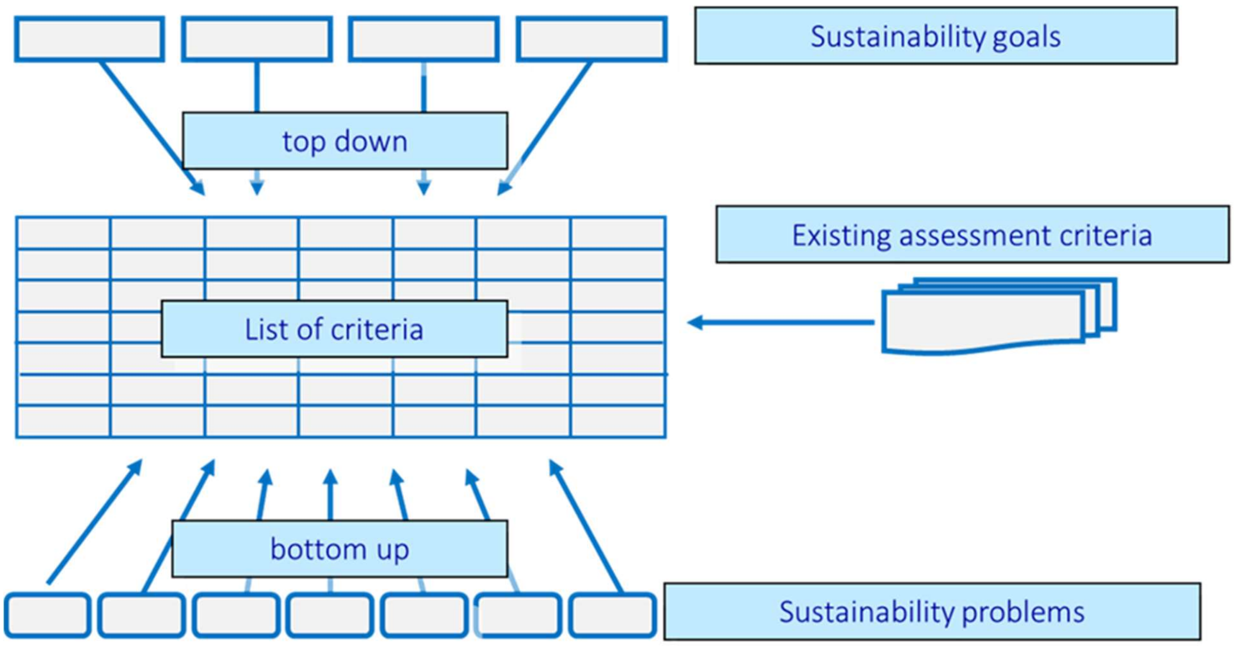

Figure 5: Methodology for developing criteria (FHTW).

4.4.2 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 (e.g., from a founder or user perspective)
- 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.

4.4.3 Development and Pre-testing Indicators and Survey

Based on the refined criteria (explained in Section 4.4.1), 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 4.4.5 for methodology and Sections 4.5.1-4.5.3 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 4.4.2) 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 4.4.5.

4.4.4 Summary of the Evaluation Scheme

The development process described in the previous sections and illustrated in Figure 4 resulted in a comprehensive evaluation scheme. This scheme (see Figure 6) encompasses 22 Sustainability Criteria, organized into seven overarching Categories. These Categories form the first column of Figure 6 and 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.

A complete list of the criteria, including definitions and underlying rationales, is provided in Appendix B (Section 9.2.1).

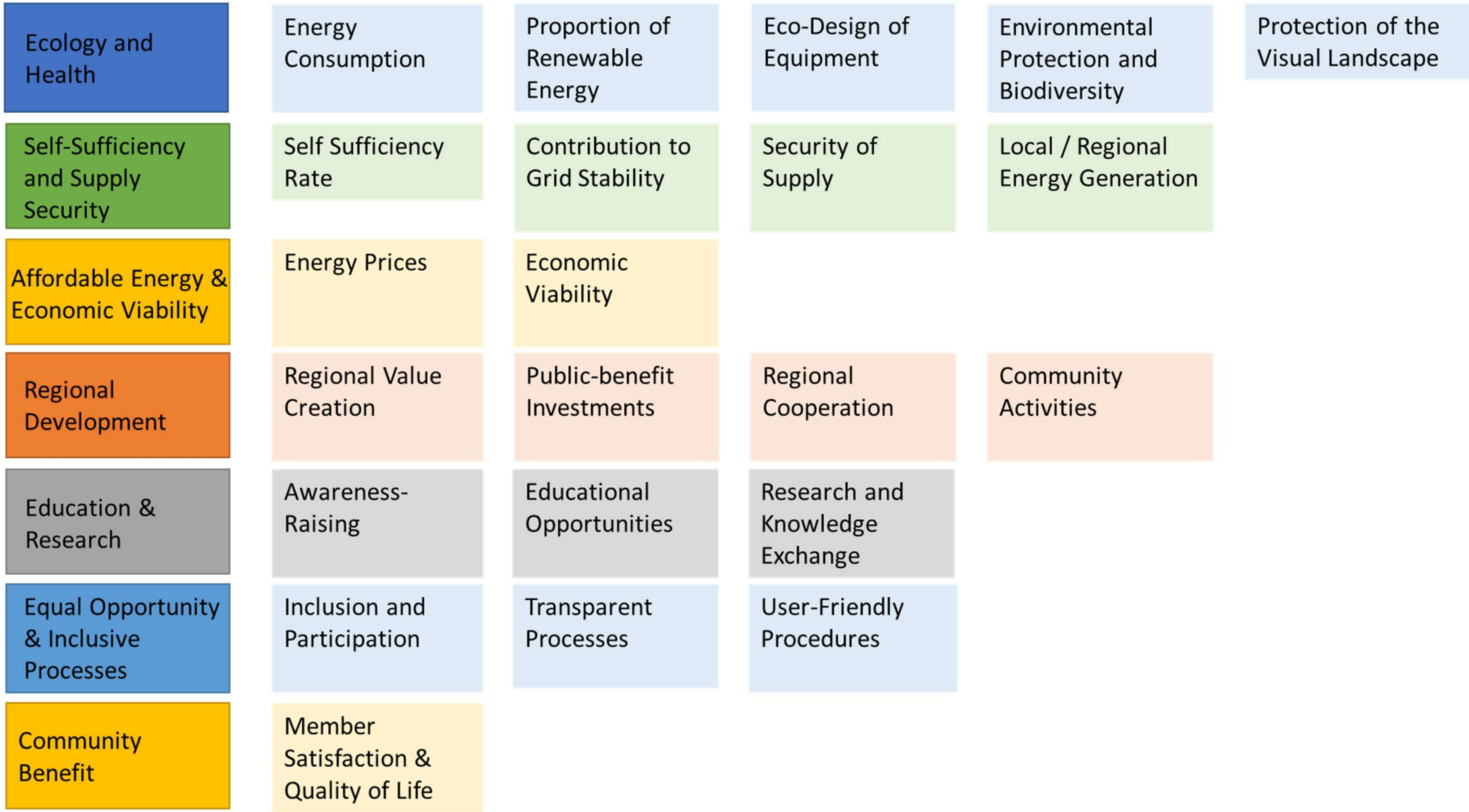

Figure 6: Overview of categories (left) and criteria (action areas) (right). (FHTW).

To support consistent interpretation, Table II provides definitions of key terms used throughout Section 4. 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 II: 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[1].	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.

[1] For a detailed discussion of how "fulfilment" is understood in the context of indicators, including important distinctions between action and completion, see Section 4.4.

4.4.5 Application of Evaluation Scheme Nationwide Survey

The evaluation scheme (Section 4.4.4) 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 4.4.6., with the overall findings summarized in Section 4.5. An English version of the evaluation tool is available Appendix B, Section 9.2.3.

4.4.6 Visualization and Feedback

The survey described in Section 4.4.5 served as the primary instrument for applying the evaluation scheme in practice. Responses to the survey questions were used to generate radar charts, which visualize the relationship between actual implementation and perceived importance across the sustainability categories. The methodology for aggregating responses from indicator level to criteria and categories—and for generating radar charts—is documented in Appendix B, Section 9.2.3. This enables EC members or other stakeholders to replicate the analysis independently using their own data.

To visualize the comparison between actual implementation and perceived importance, radar charts were created individually for those ECs that requested them (see example in Figure 7). Actual implementation was derived from responses to the indicators, which are linked to specific criteria and categories, thereby reflecting what ECs reported they were doing. In contrast, perceived importance was captured through a self-assessment in which ECs directly rated the relevance of each category. These visualizations highlighted potential discrepancies between reported practice and perceived priority. While the charts served as a diagnostic tool, they were not presented during the workshop. Instead, ECs were given the option to receive their individual results afterward.

In addition to the quantitative data, free-text responses from the survey provided valuable insights into areas where criteria or indicators might require adjustment. Based on this feedback, minor wording changes were made, and two instances of potential duplication were identified and resolved.

The final version of the evaluation tool is designed to be used independently by ECs—for both internal reflection and long-term development planning. The survey also included open comment fields for specific criteria; these responses were collected and later used in a follow-up stakeholder workshop to further contextualize and refine the findings.

It is important to note that the indicators used in this evaluation do not directly measure outcomes such as carbon reductions or economic returns. Rather, they assess whether specific practices, strategies, or organizational structures are in place—indicating that energy communities are engaging with the defined sustainability criteria. In this sense, the evaluation scheme focuses on identifying areas where action is being taken, rather than quantifying the scale or measuring the impact of those actions.

Figure 7 shows a sample radar chart comparing actual implementation and perceived importance across the seven sustainability categories. The blue curve represents implementation, based on indicator responses aggregated through the criteria and categories. The orange curve shows the self-evaluation, reflecting the EC's perceived importance of each category, as captured through direct self-assessment.

In this example, the EC appears to have directed its efforts primarily towards the Categories **Community Benefit**, **Equal Opportunity and Inclusive Processes,** and **Affordable Energy and Economic Viability**. However, the self-evaluation indicates that the EC considered the Categories **Ecology and Health**, **Self-Sufficiency and Supply Security**, and **Regional Development** to be of highest importance. The strongest alignment between implementation and perceived priority is observed in the Category **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.

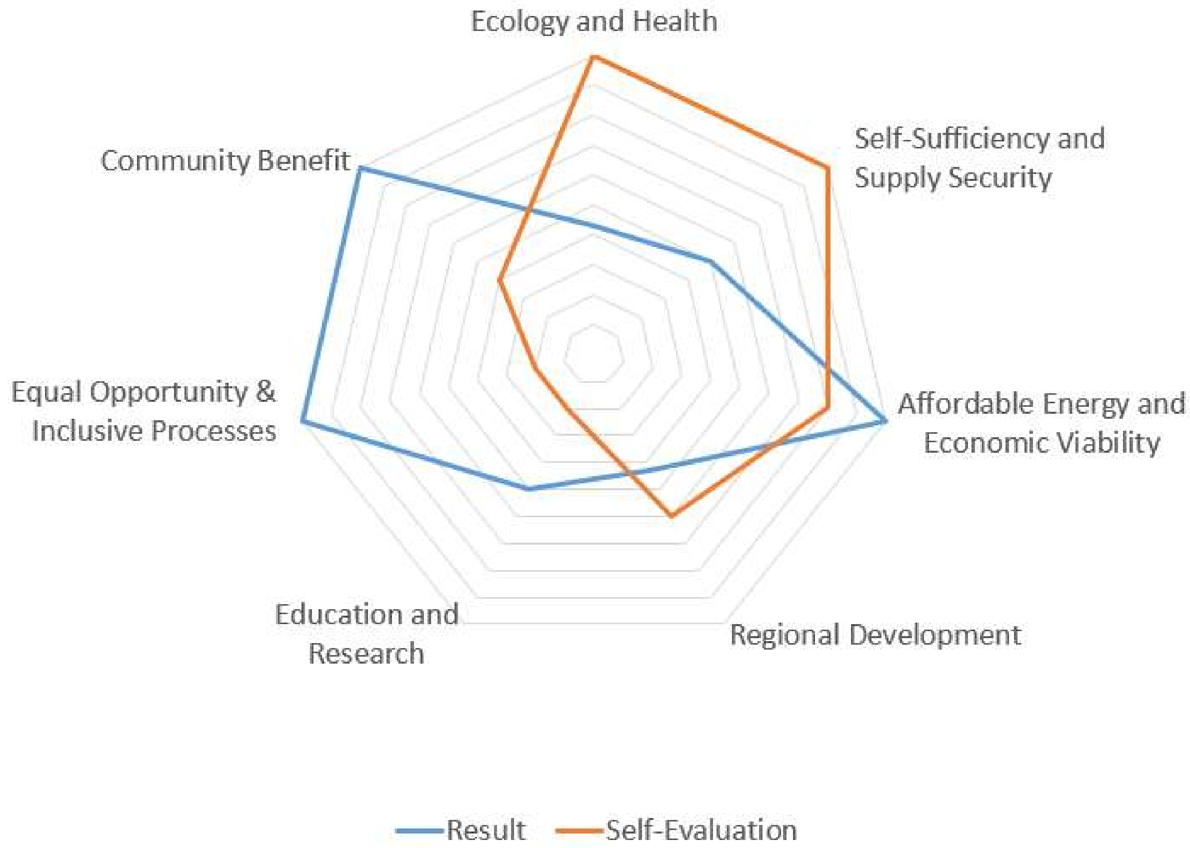

Figure 7: Case Example: Evaluation of an Energy Community (radar chart). The blue curve (Result) shows implementation based on aggregated indicator responses; the orange curve (Self-Evaluation) reflects self-evaluation of category importance from direct assessment of the survey participant (FHTW).

4.4.7 Stakeholder Workshop (Survey Follow-up)

To reflect on the usability and relevance of the evaluation scheme (Section 4.4.4) and to provide space for deeper discussion, an online workshop titled "Shaping the Future – Sustainable Pathways In and Through Energy Communities[2]" 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

[2] Title translated from the original German: Zukunft gestalten: Nachhaltige Wege in und durch Energiegemeinschaften.

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.

4.4.8 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 4.4.5) 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.

4.5 Results and Discussions

The following limitations should be considered when interpreting the results of this study. For the transdisciplinary development of the evaluation scheme, interviewees from various organizations, energy communities, and municipalities across several federal states were included (see Sections 4.4.1-4.4.7). However, the perspective of grid operators, an important stakeholder group for implementation, was missing from the data collection design. It is therefore recommended that a systematic stakeholder analysis be conducted as part of further development of the scheme, followed by the targeted inclusion of additional stakeholders, especially grid operators, in the development process.

Section 4.5.2 contains an analysis of survey results by type of energy community (LEG, REG, BEG). Due to the limited number of responses, no statistically robust conclusions can be drawn from these results. Therefore, the presented findings should be regarded as exploratory approximations, primarily intended to highlight trends and identify potential research questions for future investigations.

4.5.1 Assessment of Energy Communities Using Evaluation Scheme

The results presented in this section are based on the national survey described in Section 4.4.5, which tested the practical applicability of the evaluation scheme. The survey targeted board members and participants of energy communities across Austria. A total of 59 individuals responded, representing 55 energy communities, including 19 Local Renewable Energy Communities (LEGs), 34 Regional Renewable Energy Communities (REGs), and 6 Citizen Energy Communities (BEGs). Each participant responded individually, and board members received an extended set of questions reflecting their broader organizational perspective. Survey responses were analyzed both across the full sample and by community type. The aggregated results are discussed below, while a focused comparison by EC type is presented in Section 4.5.2.

While the evaluation scheme allows for aggregation of results to the criterion and category level, this was not implemented for the full dataset. Given the early stage of many energy communities and the emphasis on diverse, context-specific approaches, the project team chose not to present aggregated fulfillment scores. The intention was to promote open reflection rather than comparison, and to avoid unintentionally creating normative benchmarks or pressure to conform to dominant patterns. The emphasis was placed instead on empowering ECs to use the tool for internal reflection, supported by individualized feedback and qualitative interpretation.

Notably, this aggregation was applied on request for individual communities that wished to visualize their own engagement using radar charts. In these cases, the tool served as a diagnostic instrument for internal reflection and future planning.

However, selected indicator-level results for the full sample offer valuable insight into implementation patterns across categories. The following summaries highlight frequently reported practices as well as areas of limited engagement, based on survey responses to individual indicators. The analysis is organized by category and visualized in Appendix B Section 9.2.2 (Figure 22–Figure 30).

Please note: The original figures were presented in German and have been translated into English. Summaries of the corresponding findings are provided below for each category.

1. Ecology and Health (Figure 22)

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 (Figure 23)

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 (Figure 24)

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 (Figure 25)

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 (Figure 26)

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 (Figure 27–Figure 29)

Although this category was rated as less important in the self-assessment (see Section 4.5.3), 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 (Figure 30)

This category showed the highest levels of reported fulfillment. 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.

4.5.2 Diverging Practices Across Community Types

To explore how engagement with the criteria differs 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). These findings highlight how organizational structures and access to resources influence the ways in which sustainability goals are addressed.

For the Criterion **2.1: Self-Sufficiency Rate**, BEGs reported significantly higher satisfaction with their performance than REGs or LEGs. According to the survey, 100% of BEG respondents expressed satisfaction, while only around half of REG and LEG respondents reported the same. This difference likely reflects disparities in technical infrastructure and optimization capabilities. Many REGs and LEGs rely on a single generation source (typically photovoltaic systems), and approximately 40% of respondents in these groups indicated they did not use energy storage, load-shifting systems, or energy management tools.

For the Criterion **4.3: Regional Cooperation**, REGs and LEGs reported more active engagement in partnerships with neighboring energy communities or municipalities. By contrast, BEGs often cited limited access to such networks. In one open-ended response, a BEG explicitly stated that while they were interested in collaboration, they found participation in regional networks difficult to implement.

Differences were also evident for Criterion **6.3: User-Friendly Procedures**. REGs and LEGs placed more consistent emphasis on accessible participation—such as holding meetings at central locations and using plain language in member communication. BEGs, on the other hand, rated these aspects as less relevant or tended to deprioritize them in implementation.

A detailed account of these comparative findings—including indicator-level visualizations and commentary—is available in the original German version (Project Report D5). These results were also discussed during the stakeholder workshop and informed the project's final recommendations.

4.5.3 Self-Assessment and Reflections

In addition to responding to the indicator-based questions in the national survey (Section 4.4.5), 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.

Figure 8 presents the aggregated self-assessment results. 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. These discrepancies are explored further in relation to identified goal conflicts in Section 4.5.4 and form a basis for the recommendations outlined in Section 4.6.

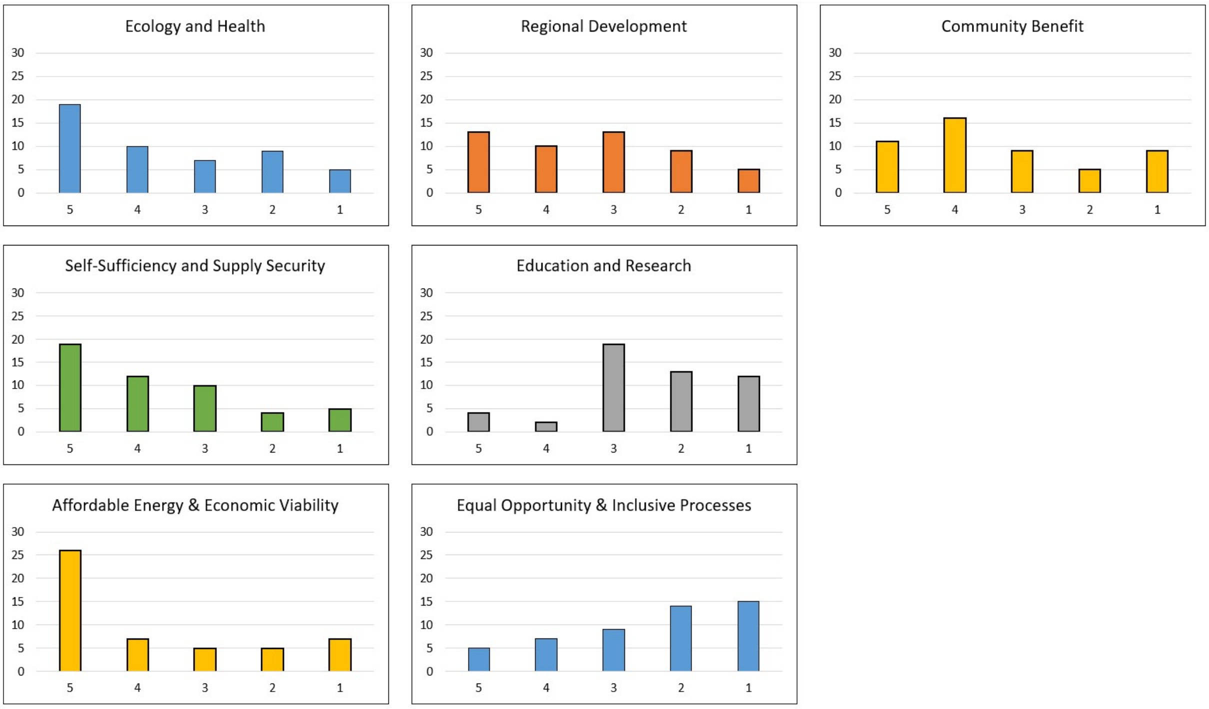

Figure 8: Self-Assessed Category Relevance - Self-assessment of category relevance by survey participants for their respective energy community. Y-axis = number of responses, X-axis = rating (5 = very relevant, 1 = not relevant), (FHTW).

4.5.4 Identified Goal Conflicts

Identifying potential goal conflicts between different dimensions of sustainability at an early stage is essential for developing effective and balanced strategies. Based on stakeholder input and project analysis, several potential conflicts were identified between specific sustainability goals. These are summarized below, along with proposed mitigation strategies (Table III).

Table III: Identified Goal Conflicts and Mitigation Strategies - Overview of identified goal conflicts between sustainability criteria and corresponding potential solutions, based on survey responses, workshop discussions and discussions of FHTW staff (FHTW).

<table>
<tr><th>Area A</th><th>Area B</th></tr>
<tr><td>Use of Multiple Renewable Energy Sources</td><td>Proximity Criterion for RECs</td></tr>
<tr><td colspan="2">The use of multiple renewable energy sources can enhance self-sufficiency and contribute to more stable generation profiles. In particular, combining solar energy with wind and hydropower is often seen as complementary due to their differing production patterns. However, in Local and Regional Renewable Energy Communities (RECs), the implementation of wind and hydropower projects is frequently constrained by proximity requirements—in Austria defined by grid topology and connection level, such as the applicable grid tier or voltage level. These restrictions can limit the integration of wind or hydropower as complementary sources to solar, particularly when technically suitable sites lie outside the permitted grid boundaries. In contrast, Citizen Energy Communities (CECs) more commonly integrate wind and small-scale hydropower, as they are not subject to the same proximity constraints and can access a broader member base for electricity sales.

Relaxing proximity rules for RECs could offer greater flexibility in combining renewable sources with complementary generation patterns. This may help energy communities better align production with local consumption and improve their financial performance. However, such a shift would also mean moving away from localized generation and consumption, which reduces the direct benefit to the grid—especially if production is not regionally coordinated. The trade-off between financial optimization and physically supportive behavior should be carefully considered when designing frameworks for integrating diverse renewable sources into energy communities. The integration of energy storage systems can help address this tension, enabling improved temporal matching of generation and demand while retaining existing proximity criteria—thus supporting both system-oriented and financial goals without requiring a shift toward more centralized or dispersed generation.</td></tr>
<tr><td>Affordable Energy Prices</td><td>Economic Viability</td></tr>
<tr><td colspan="2">The pricing structure within an energy community, as well as the use of potential financial surpluses, for example, for investments in new facilities or community projects, largely depends on the objectives defined by the community itself. Some energy communities prioritize affordable energy prices, while others align prices with market levels and use surplus revenues to fund collective initiatives for the benefit of the municipality or their members.

In principle, energy communities are not designed to operate for profit, and much of the work involved is carried out on a voluntary basis. It is therefore essential for each community to clearly define its goals in line with its values and vision. In addition, voluntary work should be explicitly recognized and appreciated, as it represents a key factor in the success of the community. Public acknowledgement, such as during events, in assemblies, newsletters, or on social media, can help express this appreciation.</td></tr>
</table>

Economic Viability	Participatory Processes
Within an energy community, prices must be regularly adjusted, new ideas heard, uncertainties addressed, member structures potentially updated, and decisions made in order to adapt to changing conditions and internal objectives. Ensuring meaningful participation opportunities can require significant time and resources, which may impact the economic viability of the energy community. In many cases, communities can only maintain their economic stability thanks to voluntary engagement. Combining active and passive participatory tools can significantly facilitate the implementation of participatory processes. It is important that decision-making mechanisms are clearly defined, for example, through majority voting or delegate models. In addition, accessing public funding schemes can help ease financial burdens and support the implementation of participatory approaches. Voluntary work plays a key role and should be appreciated through official recognition, benefits, or social events. Collaborations with businesses, municipalities, or other organizations can also help expand financial and human resources and improve the efficiency of participatory processes.	
Data Protection	Transparent Processes
A potential conflict exists between data protection and transparent processes, particularly when sensitive or personal data must be disclosed to ensure transparency. To meet both requirements, a careful balance is needed that protects the rights of individuals while maintaining the trustworthiness of the organization. Sensitive data should be processed in such a way that individuals cannot be identified. Furthermore, only the minimum amount of data necessary to ensure transparency should be collected and processed. Technical and organizational measures, such as access controls or encrypted data storage, can support both data protection and transparency objectives. In general, transparency measures should be based on the informed consent of the individuals concerned in order to uphold their rights and strengthen trust in the processes.	
Economic Viability	Regionality
The promotion of regional development and a sustainable economy often involves prioritizing the purchase of energy generation units and other technical components produced locally, in Austria, or within Europe. Utilizing local resources enables shorter transport distances, which is beneficial both environmentally and economically. However, regional products frequently struggle to compete with the prices and competitiveness of the global market, or they may simply be unavailable. However, the positive impact on regional development arising from services such as installation, maintenance, and operation of technical components, along with organizational support, should not be underestimated. Furthermore, electricity generated and sourced locally within energy communities strengthens the regional economy and frequently leads to cost savings for community members.	

Expansion of Renewable Energies	Environmental and Landscape Protection
A central goal of RECs is the expansion of renewable energy. However, this expansion can sometimes conflict with nature conservation, particularly when projects are implemented in ecologically sensitive areas or involve significant interventions in ecosystems. To mitigate this conflict, additional criteria could be developed that prioritize building-integrated photovoltaic systems and/or require the assessment of potential dual uses, such as agrivoltaics or parking lot canopies, for ground-mounted solar installations. For larger projects like wind farms or hydropower plants, environmental impact assessments are already mandatory and thus help address this conflict. However, these measures can also introduce economic trade-offs, as environmental assessments can be costly. Additionally, dedicated conservation projects can be established, and cooperation with socio-economic enterprises can be encouraged.	
Self-Sufficiency	**Grid Stability**
A conflict between self-sufficiency and grid stability can arise when an energy community aims for a high degree of independence using primarily variable renewable sources such as photovoltaics, particularly in the absence of storage or coordinated control. High levels of self-sufficiency are often pursued by installing large PV capacities relative to local consumption, which may maximize self-consumption or financial returns under traditional tariff structures. However, during peak generation periods—especially in the summer months—this can lead to significant electricity surpluses being fed into the grid, potentially contributing to local congestion or voltage instability. While these effects are context-dependent and influenced by local grid configurations, they highlight a structural tension between individual self-sufficiency and collective grid functionality. Mitigating this conflict requires a combination of technical and planning measures. These may include the integration of storage systems, demand-side flexibility, load-aware PV sizing, complementary generation sources, and grid-supportive technologies such as controllable inverters and intelligent feed-in management. Crucially, such strategies should be applied with attention to local grid conditions and coordinated planning, to ensure that increased self-sufficiency does not come at the expense of overall system stability.	

In addition to the specific goal conflicts outlined above, more general tensions may arise from evolving stakeholder roles and responsibilities—particularly as energy communities become more integrated with grid operators, regulators, and service providers. These shifts can result in conflicting interests or differing interpretations of responsibilities. Ensuring meaningful stakeholder involvement through transparent processes and clearly defined participation channels is essential to reduce friction and support coordinated decision-making. Taken together, these challenges highlight the importance of a supportive policy and governance environment. Corresponding strategies and recommendations are outlined in Section 4.6.

4.6 Recommendations

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.

The process used to derive these recommendations is summarized in Figure 9, and the resulting thematic focus areas (action areas) are outlined in Figure 10. Following these figures, the remainder of this section presents a detailed set of concrete recommendations corresponding to each focus area. These proposals address key topics such as stakeholder engagement, regulatory adaptation, evaluation methods, and capacity building, and are intended to inform both policy development and practical implementation.

Figure 9: Process for deriving action areas (FHTW).

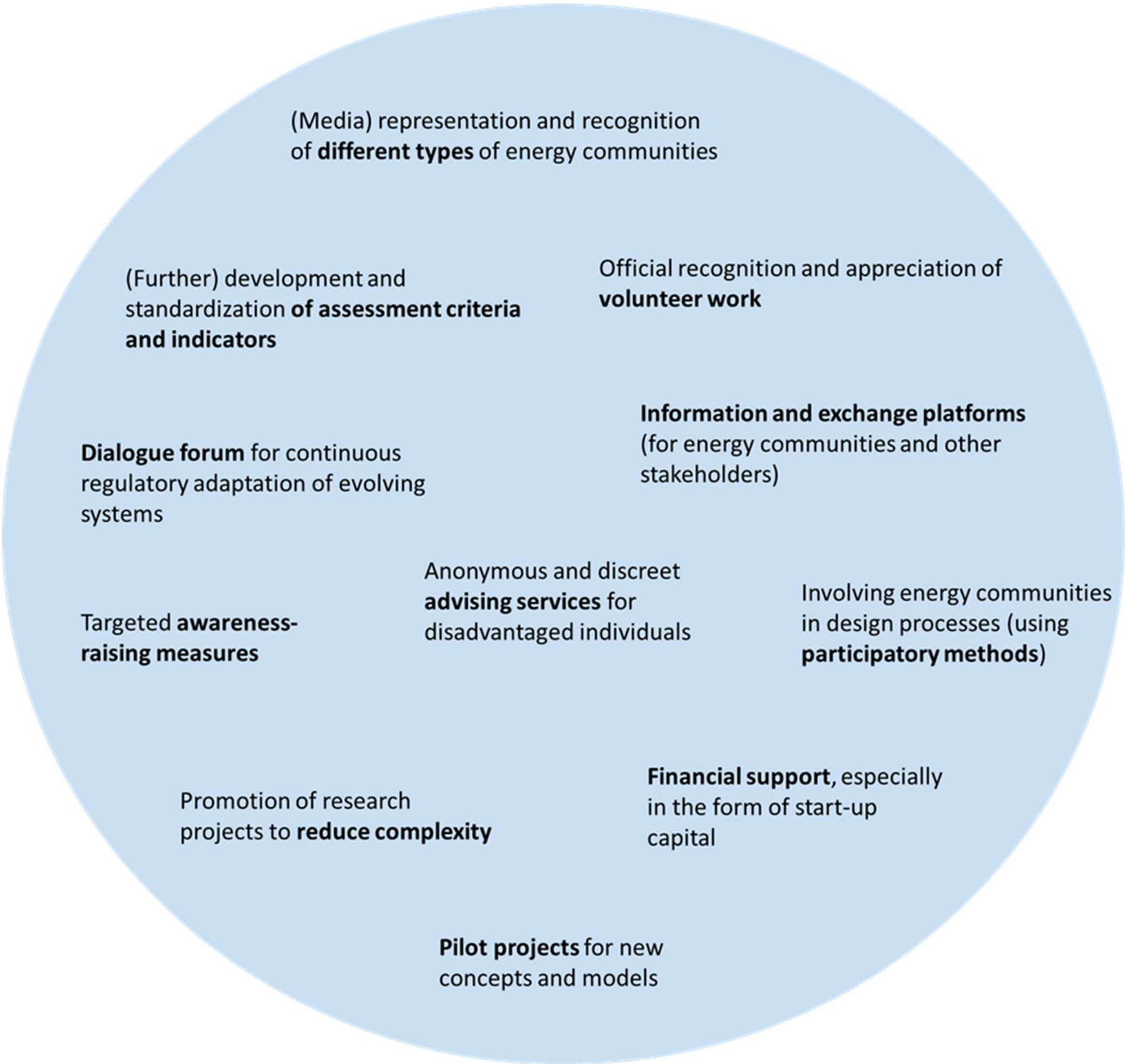

Figure 10: Overview of action areas (FHTW).

Media representation and recognition of different types of energy communities

The different types of energy communities allow for flexible ways to organize collective energy projects. Each type has its own goals related to sustainable development and offers various advantages, such as how close members are located, how the community is organized, or the legal setup. Clear media coverage and public recognition of this diversity and their contributions are important to help people understand their benefits, increase acceptance, and create suitable framework conditions for different situations.

Official recognition and appreciation of volunteer work

The voluntary commitment of many individuals is a key success factor for energy communities. Visible and official recognition of these volunteer efforts, through events, media coverage, or public awards, would greatly contribute to motivating and retaining those involved over the long term. Such appreciation also helps raise public awareness of the importance of community contributions to the energy transition.

Further development and standardization of assessment criteria and indicators

For a robust evaluation of energy communities and the operationalization of sustainability goals, the (further) development and standardization of suitable assessment criteria and indicators is essential, for example, to quantify regional value creation or to assess the environmental impact of generation facilities. Such evaluation tools enable informed, comparable, and evidence-based decisions at both operational and strategic levels.

Establishment of information and exchange platforms for energy communities and other stakeholders

To support the sustainable development of energy communities, the establishment of central information and exchange platforms is advisable. These platforms should provide evidence-based data, practical implementation examples, and harmonized evaluation and decision-making methods. Furthermore, they offer space for networking, experience sharing, and joint development of sustainable concepts and strategies. Such platforms can facilitate the initiation of collaborative projects and support well-founded (investment) decisions.

Dialogue forum for continuous regulatory adaptation of evolving systems

A regular, structured exchange between energy communities, grid operators, energy suppliers, equipment manufacturers, local and regional authorities, legislators, and other relevant stakeholders would help to adapt legal frameworks and approval processes to changing technological and organizational requirements. The dialogue should clarify and consider the needs of individual stakeholders, responsibilities, and grid demands.

Involving energy communities in design processes (using participatory methods)

Energy communities should be actively involved when creating digital tools like data management systems or billing software. Using participatory methods means listening to their real experiences and needs. This helps develop digital systems that better fit what energy communities actually require.

Anonymous and discreet advising services for disadvantaged individuals

There is a need for low-threshold, anonymous, and discreet advising services for individuals affected by energy poverty or other social disadvantages. These services can offer targeted support, provide information about rights and available options, and facilitate access to energy communities and other assistance programs.

Promotion of research projects to reduce complexity

To specifically support energy communities in their challenges, increased investment in research projects aimed at simplifying complex systems and relationships is needed. The goal is to present complex content in an understandable way and to streamline structures and processes, for example through frugal innovations or process optimization concepts. Such approaches can help relieve the burden on volunteers and facilitate practical implementation.

Promotion of pilot projects for new concepts and models

To help energy communities grow, it would be useful to support pilot projects that try out new ideas in practice. These could include new ways to set prices, manage operations, organize investments, or work together as a group. It is especially important to address social aspects and develop more flexible approaches that enable broader participation, including by groups that are often underrepresented, such as women. These pilot projects can then be used as examples for future efforts.

Targeted awareness-raising measures

To enhance knowledge and acceptance, targeted awareness-raising initiatives should be implemented. These should address key topics such as renewable energy generation, blackout scenarios, data protection and security, circular economy approaches, as well as the role and impact of energy communities within the energy transition. The goal is to enable informed participation and actively support societal transformation processes.

Financial support, especially in the form of start-up capital

To support new energy communities and accompanying initiatives, targeted financial support is necessary, particularly through the provision of start-up capital or seed funding. Funding should also be available for educational projects, informational events, and public relations measures to sustainably strengthen the development, visibility, and effectiveness of energy communities.

4.7 Conclusions

An evaluation scheme was developed through a transdisciplinary and participatory process to support energy communities in their strategic development and to provide them with a tool for self-assessment and guidance. Based on defined criteria and indicators, energy communities can assess the areas in which they contribute to sustainable development and identify aspects where they are sustainably positioned themselves. The findings enabled the identification of goal conflicts between individual criteria and problem areas, leading to actionable recommendations for decision-makers. The project results represent a first step toward a systematic evaluation of energy communities and offer impulses for the development of standardized assessment tools. Comparing different types of energy communities can help reveal structural tendencies and derive potential research questions for future studies.

The findings from this sustainability evaluation illustrate both progress and complexity within Austria's EC sector. Communities show strong performance in areas such as affordable energy and member satisfaction, while also facing challenges related to education, inclusion, and technical capacity. Importantly, these results vary by community type and governance model, reflecting the flexibility and diversity of the EC landscape.

Compared with the initial communities described in Section 3, the ECs included here generally demonstrate a higher degree of organizational maturity and broader ambition. This likely reflects both the natural progression of Austria's EC rollout and the learning that has occurred through earlier implementation. It should also be noted that many of the individuals engaged in this evaluation—particularly in Section 4—were active board members or founders of their respective ECs and thus played a central role in shaping their communities. In contrast, many of the individuals surveyed in Section 3 were participating members (limited operational involvement), having joined an existing EC rather than initiating or managing one. Together, the two studies suggest a dynamic and adaptive field—one that continues to evolve as new policy tools, digital infrastructure, and evolving user expectations continue to shape the role of energy communities in Austria's energy transition.

5 Digital Tools for Energy Communities

5.1 CDEP

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.

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. See Figure 11.

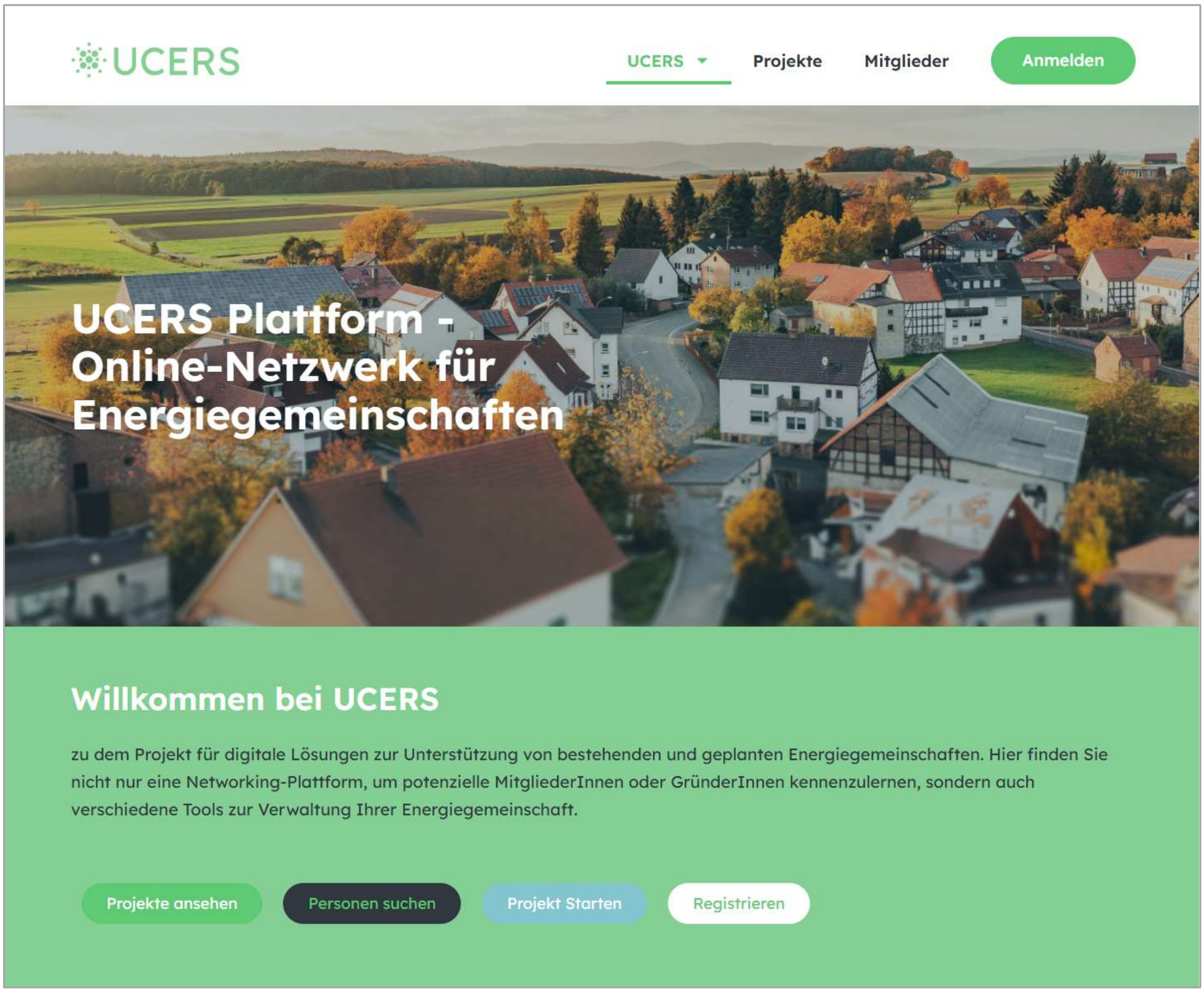

Figure 11: UCERS Homepage (FHTW).

Informational Pages: A series of informational pages provide accessible explanations of how energy communities work, what benefits they offer, and what tools are available to support them. These pages are intended to guide users through core concepts and help demystify the legal, technical, and social elements involved in community energy.

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. See Figure 12.

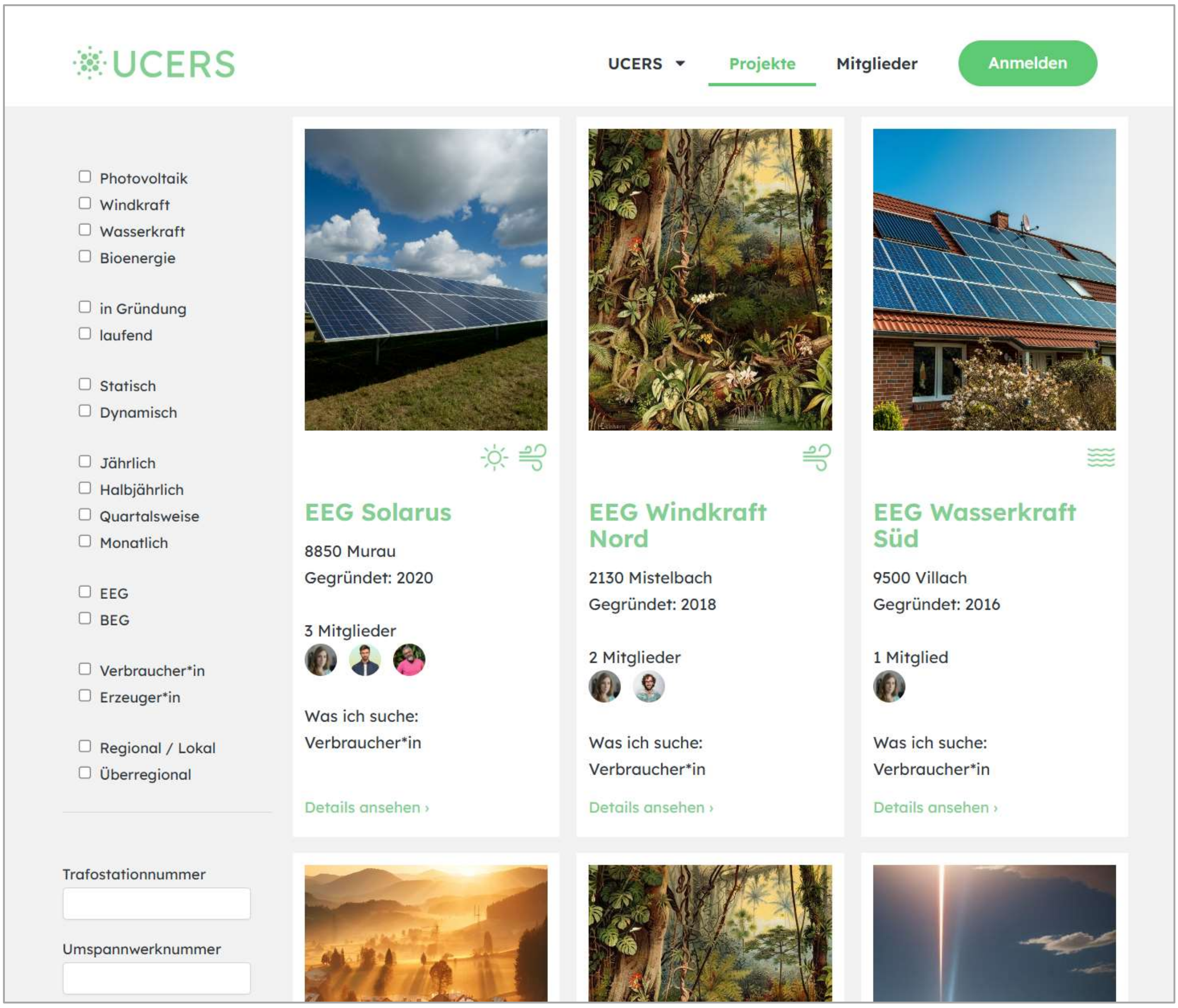

Figure 12: UCERS Project Page – Search for Energy Communities (FHTW).

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.

5.2 COOP

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.

5.2.1 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.

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. See Figure 13.

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.

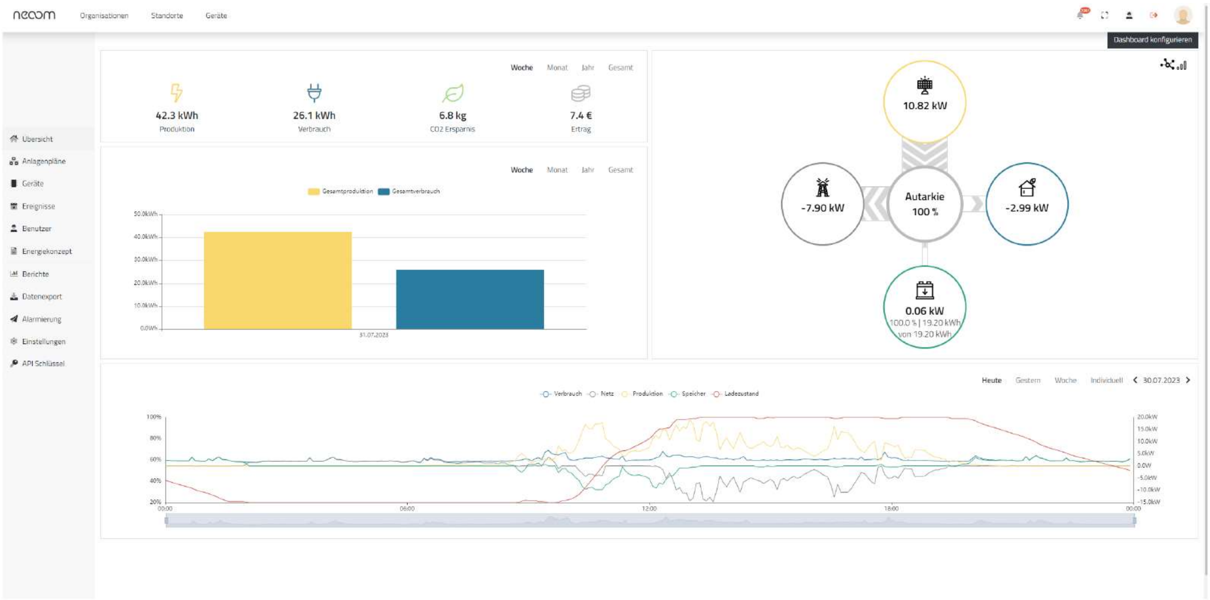

Figure 13: Example of Energy Community Monitoring from neoom (neoom).

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.

The findings and lessons learned from this deployment—including technical, economic, and social impacts—are discussed in more detail later in this report.

5.2.2 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 14 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 15 for an example.

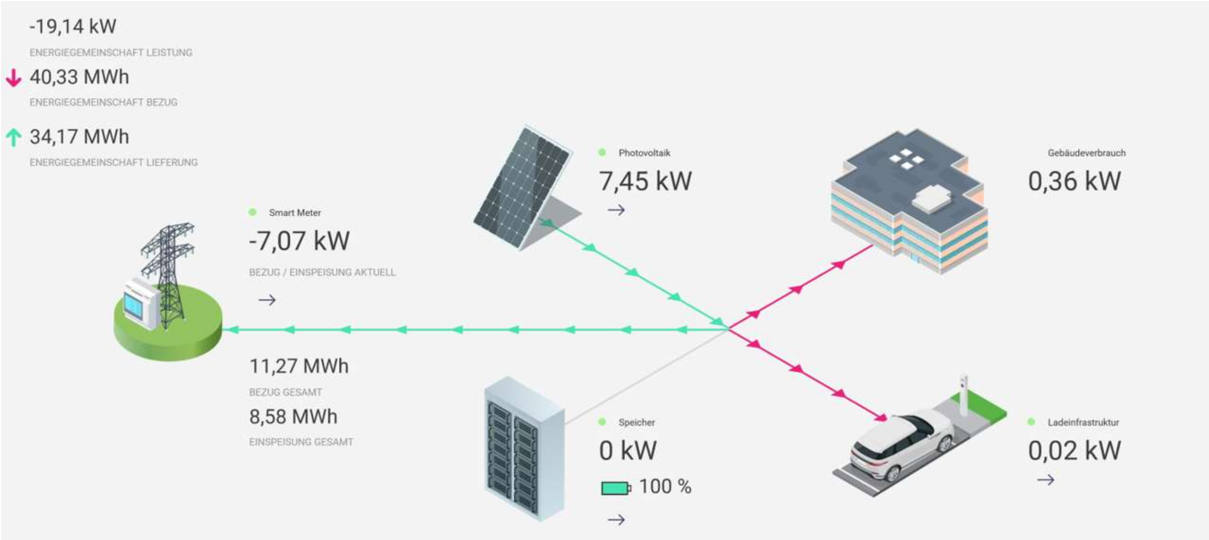

Figure 14: Single Member Energy Profile - Detailed view of a single member's energy profile, showing personal generation, consumption patterns, storage utilization, and contribution to community energy exchange (RSO).

These elements were deployed in a residential energy community to support the coordination of local energy usage, improve transparency, and facilitate more active participation from end users. The monitoring tools provided insights into total and individual power flows, enabling both operational decisions and long-term strategic planning. Through this setup, the platform supported the alignment of energy consumption with locally available renewable generation, helping to minimize reliance on grid-supplied electricity.

Figure 15: 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. See Figure 16 for an example.

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 6.

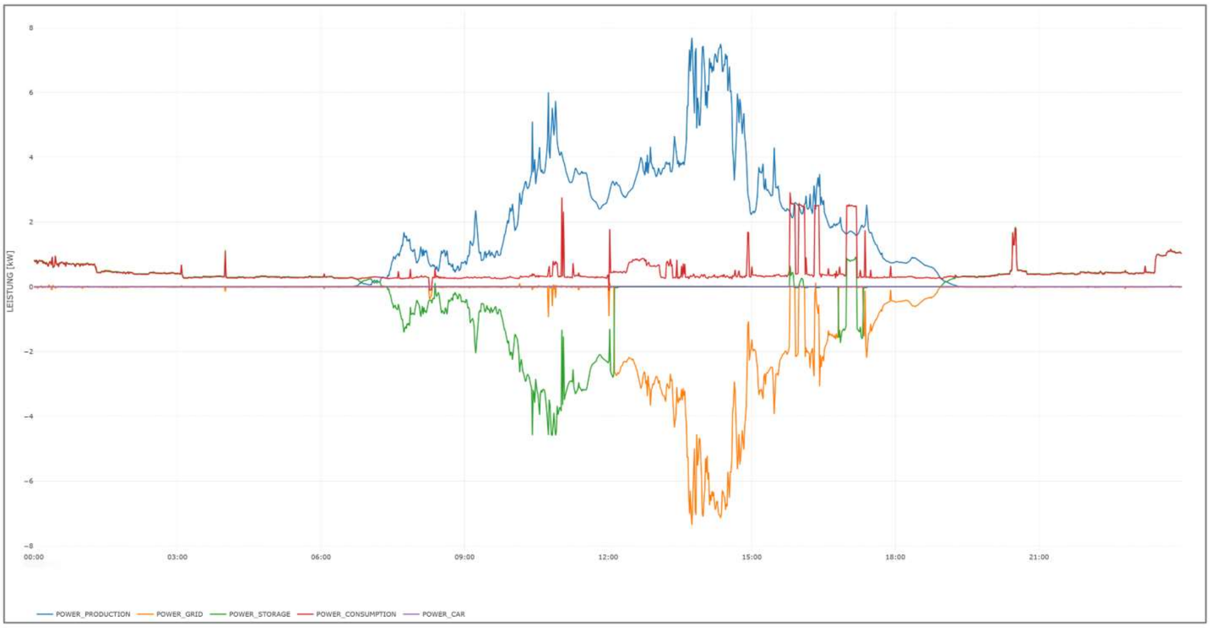

Figure 16: Historical Dashboard Data - Historical data view from the dashboard, showing past energy production, consumption, and storage performance for analysis and optimization purposes (RSO).

5.2.3 Integration of Energy Storage

As part of a dedicated line of work on cooperative energy optimization, the UCERS project investigated how the performance of energy communities could be enhanced through the strategic use of residential storage systems and forecast-based energy planning. These investigations were carried out through a collaboration between 4ward Energy Research and neoom, who combined domain expertise in energy storage systems and data-driven modelling. Their efforts focused on the question of how intelligent storage operation—supported by predictive algorithms—could contribute to increased self-sufficiency, cost efficiency, and coordinated energy use within a community setting.

The analysis built on real consumption data from existing energy communities and tested a range of modelling and optimization strategies, with the aim of informing implementations of advanced energy management practices.

5.2.3.1 Machine Learning for Consumption Forecasting

One part of the investigation focused on the development of machine learning (ML) models to forecast electricity consumption in energy communities. The motivation was to assess whether a “soft sensing” approach—using aggregated smart meter data combined with weather inputs—could provide sufficient accuracy to support storage planning, potentially avoiding the need for widespread installation of real-time measurement infrastructure.

Smart meter data from an energy community comprising 36 mixed residential participants served as the training dataset. The models evaluated included Random Forest Regressors, Neural Networks, and gradient boosting methods such as XGBoost and LightGBM. Weather data (temperature, solar irradiation) and time-related variables were integrated as exogenous inputs.

Initial attempts to predict full 15-minute load profiles proved unreliable due to high variability and the relatively small participant pool. As a result, the team shifted to a simplified approach, forecasting average daytime and nighttime consumption values. This reduced temporal resolution improved model stability and produced more consistent results, particularly for the nighttime period—a time when solar generation ceases, and stored energy becomes a key supply source.

Model accuracy was evaluated using standard error metrics, with results indicating that nighttime forecasts were significantly more reliable, due in part to more predictable user behavior during these hours. The findings suggest that intelligent storage discharge during night periods, guided by such forecasts, could be an effective strategy for maximizing alignment between supply and demand.

5.2.3.2 Simulated Storage Operation for Energy Community Optimization

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.

5.2.3.3 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. In this context, adapting internal pricing structures within energy communities—for instance, by introducing incentives for feeding electricity into the grid during periods of lower solar production, such as early mornings or evenings—could encourage behaviors that support both individual savings and greater energy self-sufficiency at the community level. More broadly, aligning local energy use with market signals may enhance the overall economic viability of energy communities in the evolving energy landscape.

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.

Additional methodological details, household-level results, and scenario comparisons can be found in Appendix C (Section 9.3). This supplementary material provides further context for the findings presented here and illustrates how the reported outcomes were derived.

6 Testbed Implementations and Empirical Insights

This part of the project focused on the implementation, operation, and evaluation of energy communities in real-world settings. The core objective was to investigate how local energy production could be more effectively utilized and shared within and between communities. In particular, the work explored the potential of energy communities to increase local self-consumption, facilitate energy exchange among members, and assess whether combining multiple communities could enhance overall energy sharing and flexibility. These efforts aimed to contribute to the development of scalable and user-centered community energy models.

So called **Tech-Communities** (testbeds) were implemented in several real-world testbeds involving households, apartments, municipal facilities, and commercial buildings. These testbeds utilized hardware and digital solutions that were developed or adapted by project partners, including platforms for energy optimization, advanced monitoring systems, and flexible organizational structures. The testbeds served as environments for testing how technical and social configurations influence the capacity of communities to coordinate energy production and consumption, especially under varying local conditions.

Baseline-Communities (testbeds), by contrast, represented simpler energy community models. These relied on existing photovoltaic and battery systems at individual residential or commercial sites and employed standard local self-sufficiency algorithms. Energy sharing in these communities was based primarily on smart meter data used for billing purposes, with limited intervention or additional technical infrastructure. While more limited in scope, these communities served as useful reference cases for evaluating the benefits of more sophisticated setups.

All communities were monitored over extended periods—ranging from several months to two years—depending on site availability and data access. This allowed for detailed assessment of energy flows, user behavior, and the effects of various coordination strategies. In some cases, the project also investigated the potential to link or combine communities to facilitate broader energy exchange and improve system-level efficiency.

6.1 Selection Criteria for Testbeds

To ensure comprehensive and representative results for the UCERS project, the selection of testbeds was strategically designed to reflect a diverse cross-section of energy consumption and production environments within Austria. This approach aimed to capture a broad spectrum of technical, social, and economic factors influencing the successful implementation of energy communities. The chosen testbeds include a balanced mixture of public and commercial buildings, single-family homes, and apartment complexes. This variety allows for the evaluation of the developed platforms under different operational conditions, user behaviors, and infrastructure complexities.

The testbeds were selected based on their relevance to key project partners and their ability to showcase various configurations of renewable energy technologies such as photovoltaic (PV) systems, battery storage, electric vehicles (EVs), and heat pumps. The selected sites are described in Table IV.

Table IV: 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	1 Building 7 Apartments 1 EC	Apartment Building with PV System

The selection of testbeds aimed to reflect a balance of different building types and participant profiles—including single-family homes, apartment buildings, and business sites—in order to explore a range of real-world energy community configurations. While this variety was an important consideration, the final selection was also shaped by practical factors, such as the availability of partners' existing infrastructure, technical readiness, and the willingness of local participants to engage in specific aspects of implementation. As a result, the chosen testbeds offer a diverse, though not exhaustive, sample of community energy settings relevant to the Austrian context. The following sections present further details for each testbed.

6.1.1 neoom: Public and Commercial Buildings with PV and Battery

The neoom testbeds involved public and commercial buildings equipped with photovoltaic (PV) systems and battery storage. These types of facilities typically have relatively high energy use during operational hours and present meaningful potential for increased self-consumption, self-sufficiency and local flexibility. By combining PV with battery systems, these buildings can better manage their energy flows, reduce peak loads, and support local grid stability.

The testbeds made use of existing energy systems at the participating sites, including PV installations and battery storage, with project activities focusing on integration, data acquisition, and coordination rather than new system installation. The PV system sizes ranged from approximately 25 to 260 kWp and were paired with lithium iron phosphate battery systems, each providing around 20 kWh of storage capacity and a charge/discharge power of 10 kW.

To support energy management across sites, the testbeds integrated hardware and digital tools provided by project partner neoom. These included the BEAAM IoE Gateway, which connected inverters, batteries, and smart meters, and the neoom CONNECT platform, which enabled real-time optimization of energy flows, including load balancing and demand-side strategies. At the community level, the neoom KLUUB platform aggregated operational data from multiple users, supported day-ahead forecasting, and enabled participant engagement through the neoom App.

These tools were adapted and further developed during the project as key components of the Community Operation & Optimization Platform (COOP). Their implementation in several testbeds allowed for the practical validation of COOP's modular concept—demonstrating how decentralized energy systems can be coordinated to enhance efficiency, transparency, and community-wide self-consumption.

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

The Reisenbauer/Energy-Climate (RSO/ENC) testbed includes single-family homes that integrate various combinations of photovoltaic systems, battery storage, electric vehicles (EVs), and heat pumps. These technologies are becoming increasingly common in Austrian households, making this group a valuable case for studying household-level participation in energy communities.

The participating homes vary in energy demand and the degree of technology adoption, offering a realistic view of decentralized production and consumption. The combination of energy generation, storage, mobility, and heating in these homes provided an opportunity to examine how households can coordinate energy use and contribute to local energy resilience. It also offered insight into user behavior and engagement with energy systems in everyday settings.

The testbed made use of existing household energy systems, including PV, battery storage, heat pumps, and electric vehicles, with project activities focusing on integration, data acquisition, and coordination rather than new system installation. The photovoltaic system sizes ranged from small-scale installations of 800 watts up to approximately 16 kWp. Battery storage systems were present in two homes, with capacities between roughly 20 and 30 kWh.

To enable real-time energy monitoring and community coordination, project partner Reisenbauer installed measurement and data acquisition systems in each household. These included energy meters and monitoring interfaces linked to the existing devices, using both wired and wireless communication protocols. The system unified data from diverse sources and supported initial optimization efforts such as improving self-consumption, identifying flexible loads, and evaluating potential for energy sharing among community members.

The systems developed and deployed by Reisenbauer in this testbed contributed to the Community Operation & Optimization Platform (COOP). These efforts focused on creating flexible, interoperable solutions for distributed residential settings, enabling detailed energy monitoring and laying the groundwork for responsive community-level coordination.

6.1.3 Spitzer: Commercial Buildings with EV Integration

The Spitzer testbed focused on commercial buildings incorporating electric vehicle (EV) charging infrastructure into their broader energy systems. As electric mobility becomes more widespread, commercial properties are increasingly relevant sites for managing charging demand in coordination with existing loads.

This testbed allowed the project to explore how EV charging can be integrated into energy management practices in commercial settings. It also provided an opportunity to consider how businesses might contribute to energy communities by managing flexible loads and offering energy-related services, such as public EV charging. The experience offered practical insight into both the challenges and potential of EV integration in this context.

While technical implementation was limited due to grid capacity constraints and long equipment lead times, the testbed focused on the strategic preparation of a commercial energy community. This included assessing the readiness of participating sites—such as Urkraft Arena (144 kWp PV), DREI Tannen Bad (consumer-only), and Impulszentrum Vorau (59 kWp PV)—for further infrastructure expansion. Project activities also addressed the design of cost-sharing models, legal governance structures, and membership frameworks, laying the groundwork for future deployment of scalable commercial energy communities.

6.1.4 Fronius: Apartment Building with PV System

The Fronius testbed involved a multi-family apartment building equipped with a shared photovoltaic (PV) system. This setting illustrated the particular challenges of implementing renewable energy solutions in multi-tenant buildings, where technical, legal, and organizational issues tend to be more complex than in single-family homes.

The testbed allowed the project to examine how collective energy generation could be managed within a shared residential environment. Key areas of focus included the distribution of energy among residents, billing arrangements, and strategies for engaging users in a cooperative energy model.

A centrally installed 30 kWp PV system supplied electricity to both the individual apartments and the building’s communal facilities, with energy flows managed across eight metering points. The system was independently financed and implemented by the apartment owners, with support from the project team during the planning and installation phases—including assistance with ordering equipment, applying for funding, and establishing the energy community. This reflected a self-organized, community-driven approach to renewable energy adoption in a multi-tenant context, facilitated through collaboration during the project.

To manage energy monitoring and system oversight, the testbed used the building’s existing smart meter infrastructure in combination with the Austrian Energy Data Exchange (EDA), which provided analysis of energy production and consumption. In addition, the PV system's manufacturer app enabled convenient access to real-time system performance data, supporting both operational oversight and user engagement. The Fronius testbed demonstrated how a relatively simple technical setup, combined with collaborative organization, could effectively support community-based renewable energy in an apartment setting.

6.2 Monitoring and Analysis Methods

6.2.1 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.

6.2.1.1 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.

6.2.1.2 Monitored Metrics

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.

6.2.1.3 Measurement Intervals

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.

6.2.1.4 Tools and Systems Used

The technical monitoring infrastructure leveraged specialized tools and systems provided by two project partners:

- **neoom Tools**: The neoom BEAAM IoE Gateway facilitated the integration of various energy assets, while the neoom CONNECT platform enabled real-time monitoring, control, and data visualization. The neoom KLUUB platform aggregated data across community members for coordinated energy management.
- **RSO Tools** (Reisenbauer Solutions GmbH): Reisenbauer implemented advanced energy management controllers and monitoring devices tailored for household-level data acquisition. These systems integrated data from PV inverters, battery storage systems, and smart home devices, ensuring comprehensive visibility into household energy flows.

6.2.1.5 Social Monitoring

The following metrics were used to assess social engagement and acceptance:

- **User Acceptance:** Measured through participant satisfaction with the technology, perceived reliability, and willingness to continue or expand participation in the energy community.
- **Participation Rates:** Tracked by monitoring active involvement in community decision-making processes, attendance at workshops, and responsiveness to surveys.
- **Engagement Levels:** Evaluated based on user interaction with monitoring tools adoption of energy-saving behaviors, and proactive engagement in optimization initiatives.

Insights gained from these metrics were critical for identifying barriers to engagement and developing targeted strategies to enhance user involvement.

Social monitoring was conducted under Work Package 2 (WP2) to assess user engagement, acceptance, and participation within the energy communities. This aspect of monitoring aimed to capture the human and behavioral dimensions that influence the success and scalability of energy communities. A summary of these results are included in Section 3.

6.2.1.6 User Feedback Collection Methods

To gather qualitative and quantitative feedback from participants, a combination of surveys, workshops and interviews were conducted. For additional detail, see Section 3 and the corresponding appendix for survey and interview findings, as well as Section 4 and its appendix for insights derived from the workshops conducted under Work Package 5.

6.2.1.7 Data Privacy and Security Measures

The UCERS project placed a high priority on data privacy and security to ensure participant trust and regulatory compliance. The following measures were implemented:

- **Purpose Limitation:** Data collected was strictly used for research, analysis, and optimization within the scope of the UCERS project. Clear boundaries were established to assure appropriate handling of data.
- **Access Control:** Only authorized project team members had access to raw data. Access permissions were role-specific and regularly reviewed to prevent unauthorized data handling.
- **Data Anonymization:** Efforts were made to eliminate and minimize any personal data. Remaining personal data were anonymized prior to analysis to protect individual identities. Aggregated data were used for reporting and dissemination purposes.
- **Secure Data Transmission and Storage:** Secure authentication methods were employed to safeguard data during transmission and storage.

By implementing these measures, the UCERS project ensured that participant data was handled responsibly, maintaining transparency and trust throughout the project lifecycle.

6.2.2 Data Preparation and Validation Approach

To ensure reliable results in the scenario analysis, the measurement data collected from the testbeds underwent a structured, multi-step validation and preparation process. This was essential for producing a consistent and accurate dataset that could support meaningful comparisons across different energy community configurations.

The data preparation was carried out using an automated process, which included plausibility checks, the handling of missing values, and the correction of physically implausible measurements (such as negative energy consumption). Specific strategies were applied to complete incomplete battery and PV data, identify and remove outliers, and estimate missing grid values using logical rules and historical data. These procedures ensured internal consistency across energy flows from PV production, battery storage, grid import/export, and building consumption.

This process was especially important for testbeds with high-resolution monitoring infrastructure, where the quality of the analysis depended on the completeness and plausibility of the recorded values. The final dataset enabled robust simulation of different energy community configurations and the calculation of key indicators, such as self-sufficiency and self-consumption ratios.

For a detailed description of the data preparation steps, including the logic used for handling gaps and inconsistencies, see Appendix D, Section 9.4.

6.2.3 Community Scenario Analysis

6.2.3.1 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 in terms of its impact on local self-sufficiency and the potential for cost savings among participating members. Simulation parameters were adapted to the specific characteristics of each testbed, including the number of participants and the available infrastructure, in order to reflect conditions relevant to practical implementation.

The scenarios were applied within defined testbed groupings (e.g., neoom, RSO/ENC), consistent with the project's focus on realistic and geographically or operationally coherent local and regional energy communities. While it is technically feasible to combine all testbeds into a single energy community, such a configuration was not a primary focus of the analysis, as it aligns more closely with the concept of a cross-regional citizen energy community (a BEG) rather than localized energy sharing.

For the neoom testbed, Scenarios 0 through 4 were applied. Buildings T1 to T5 were grouped into Energy Community 1 (EC1), and buildings T6 and T7 into Energy Community 2 (EC2), which was relevant for Scenario 1. In Scenario 2, all seven buildings were integrated into a single energy community. Scenario 3 introduced a variation by replacing building T2 (a prosumer) from EC1 with a consumer-only profile, achieved by removing local production and storage capabilities from the simulation. In effect, Scenario 3 repeated the configuration of Scenario 1 for EC1, modifying only T2's role by excluding its production and storage functions to simulate a consumer-only profile. Each of these four scenarios was assessed using both static and dynamic energy allocation methods.

For the RSO/ENC testbed, a similar approach was followed, with the exception that Scenarios 1 and 3 were not included. Scenario 1 was not applicable, as the testbed already consisted of a single unified energy community. Scenario 3 was excluded due to insufficient data for the type of variation required.

The results for neoom's second testbed, EC2 (T6–T7) under Scenario 1, as well as Scenario 2 (a combined EC1 and EC2) and the RSO/ENC testbeds, are omitted in Section 6.3 for brevity but are included in the full Monitoring Evaluation Report (D6) and available upon request.

6.2.3.2 Static and Dynamic Allocation Methods

In addition, the analysis distinguishes between two types of energy allocation methods commonly applied in Austrian energy communities: static and dynamic allocation. These approaches define how locally generated renewable energy is distributed among community members for billing purposes.

In **static allocation**, fixed shares of the shared energy—expressed as predetermined percentages—are assigned to each participant based on prior agreements. These shares remain constant over time, regardless of when or how much electricity is actually consumed by individual members. Any surplus energy not used by a participant within their allocated share is sold outside the energy community.

Dynamic allocation, on the other hand, is time-based and adjusts according to actual consumption behavior during each 15-minute settlement interval. Instead of relying on fixed percentages, energy is allocated proportionally based on each member's consumption relative to the total consumption of the energy community within that interval. This method is defined within Austrian regulatory frameworks governing energy communities.

In practice, dynamic allocation increases the share of locally generated electricity that is accounted for within the energy community during billing. Because allocation is based on 15-minute interval consumption values, a larger portion of generation can be distributed among members rather than being allocated for external sale. While the physical energy flows remain unchanged, this approach can improve the economic balance for participants by reducing the volume of energy settled at lower feed-in tariffs and increasing the share settled at internal community rates. This approach highlights the potential of dynamic allocation to enhance the economic value of local renewable generation by aligning billing outcomes more closely with real-time consumption behavior.

6.2.4 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.

6.3 Results and Discussion

The analysis presented in Section 6.2 described a broad set of energy-related indicators—including energy production and consumption, self-consumption and self-sufficiency ratios—across various combinations of community scenarios and energy allocation methods (static versus dynamic). In addition, economic assumptions were explained.

This section summarizes the key findings, with a particular focus on self-sufficiency ratios and economic outcomes, which were considered the most relevant for evaluating the operational and financial viability of different energy community setups. While the results point to several promising patterns, they should be considered in light of the underlying limitations in the data and testbed designs. A more detailed presentation of all monitored metrics and secondary results is available in the full Monitoring Evaluation Report (D6) and can be provided upon request.

6.3.1 Limitations of Findings

Several important limitations should be considered when interpreting these results. Most notably, the findings are primarily based on commercial buildings within neoom's Tech-community testbeds. While these testbeds offer a controlled environment and high-quality data—supported by multi-year monitoring—they represent a specific subset of potential energy community participants. The relatively small number of participants per testbed, combined with their over-producing profiles (i.e., high photovoltaic-to-load ratios), means the results may not fully reflect the dynamics of more balanced or residential-based communities.

Furthermore, participating buildings used only PV systems as generation sources. While this aligns with the current market reality, in which PV is often a readily available and cost-effective renewable option, it does not allow conclusions to be drawn about the behavior of ECs involving other technologies such as wind or small hydro—which provide generation during different times of day and thus affect community performance differently (e.g., night-time load coverage). In addition, the study focused exclusively on electricity sharing within the energy communities.

Household data from the RSO/ENC communities proved insufficient in quantity to support robust conclusions. While this is a limitation, it also reflects a broader challenge in the sector: advanced features such as flexible allocation may be more feasible to implement initially in communities with fewer but larger participants, even though the long-term goal remains broad inclusion of diverse members, including households and apartment dwellers. Addressing this gap remains an important area for future research and implementation.

Finally, the Baseline-Community residential testbed from Fronius—which operated with minimal additional hardware—provided valuable insights. Its high-quality, year-long data served as a useful reference case, demonstrating that even low-complexity energy communities can achieve meaningful economic and energy performance outcomes when effectively configured.

6.3.2 Results of Tech-Communities

The testbeds referred to as Tech-Communities were developed to examine how energy communities operate under conditions that incorporate digital tools and control systems. These environments included a mix of public, commercial, and residential sites equipped with photovoltaics, battery storage, and—in many cases—automated monitoring and management solutions. By supporting real-time coordination of energy assets and enabling adaptive management, these testbeds reflect technically supported community models. The following section presents empirical findings on energy performance, economic outcomes, and system dynamics observed across these sites.

6.3.2.1 Improvements in Self-Sufficiency

The formation of energy communities led to improvements in self-sufficiency for individual buildings, as evidenced by test data from the neoom testbed for EC1. Figure 17 compares Scenario 0, in which each building operates independently (labeled Rss), with Scenario 1 for Energy Community 1 (EC1), showing results for both static (Rss_stat) and dynamic (Rss_dyn) allocation. The results for EC2 (T6–T7) are not shown here for brevity but are included in the full Monitoring Evaluation Report (D6) and can be provided upon request.

Under static allocation, self-sufficiency improvements were minimal, reflecting the limited benefit of applying fixed distribution rules in a context where generation already exceeds local demand. In contrast, dynamic allocation produced more noticeable, though still moderate, gains—typically in the range of +1 to +5 percentage points. These improvements are attributable to the time-based matching of generation with actual consumption, which allows for more efficient internal allocation of shared energy.

However, the overall impact of both allocation methods was constrained by a common feature of the testbeds: a high production-to-consumption ratio. Many buildings were equipped with relatively large photovoltaic (PV) systems—approximately 1–2 kWp installed per 1,000 kWh of annual demand—resulting in a structural surplus of generation. As a result, many participants already achieved a high level of self-sufficiency when operating individually, and the potential for further gains through community sharing was inherently limited. This context is essential for interpreting the relatively modest changes observed across scenarios.

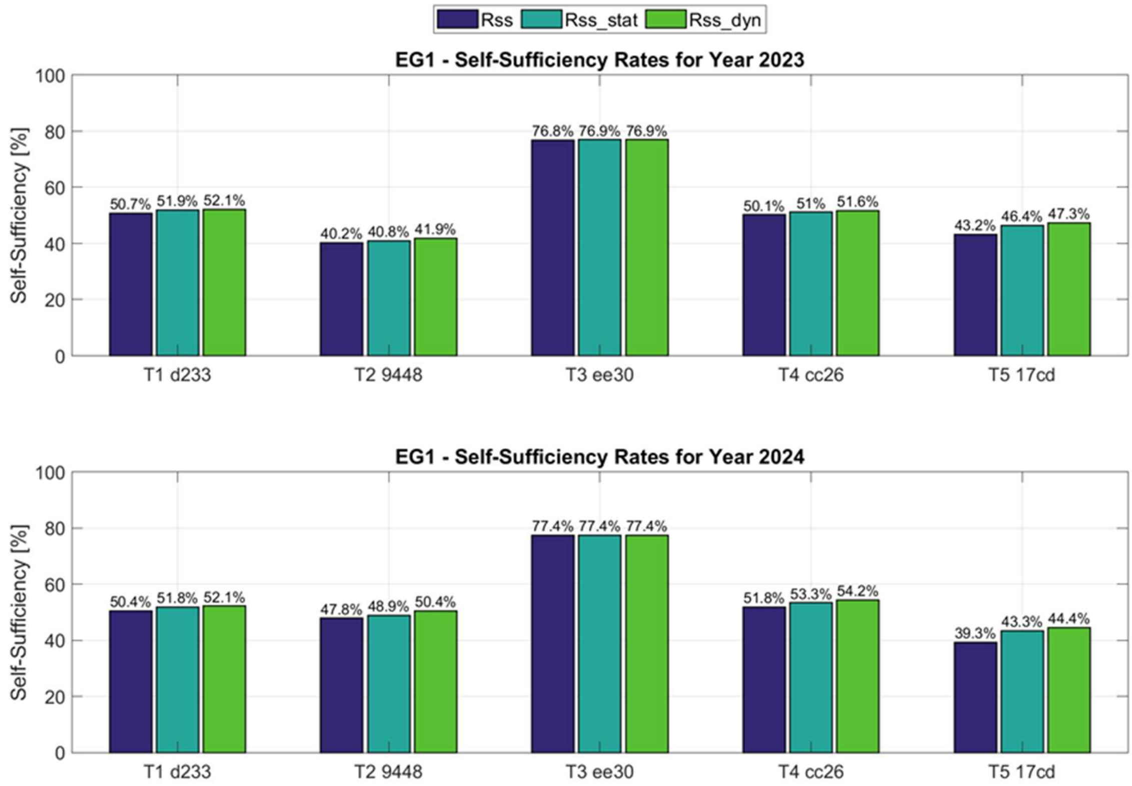

Figure 17: Self-Sufficiency Scenario 1 (T1–T5 as Prosumers) – Self-sufficiency rates (2023–2024) for Scenario 0 and Scenario 1 in Energy Community 1 (EC1), neoom testbed (T1–T5), where all buildings are configured as prosumers. Scenario 0 represents individual operation with no community coordination (labeled Rss). Scenario 1 shows results under a two-community setup with EC1 participation, using static (Rss_stat) and dynamic (Rss_dyn) energy allocation. Results reflect the limited potential for self-sufficiency gains in over-producing communities (FHTW).

More substantial benefits were observed when the composition of the energy community was adjusted to include a non-producing member, as in Scenario 3. In this targeted configuration, testbed participant T2—originally a prosumer—was modeled as a pure consumer by removing its local PV generation from the dataset. This allowed for an assessment of the effects of energy community participation on a consumer-only profile. The results showed a significant increase in self-sufficiency for T2, rising from 0% to nearly 30% (see Figure 18). The comparison again uses Scenario 0, in which each building operates independently (labeled Rss), and Scenario 3 for EC1, showing outcomes for both static (Rss_stat) and dynamic (Rss_dyn) allocation.

While this level of performance is comparable to that of a typical standalone PV system without storage, it was achieved here solely through participation in the energy community—without the need for additional hardware. This finding underscores the potential value of strategically configuring community composition. In particular, the integration of consumers into producer-heavy communities offers a low-barrier approach to improving both individual and collective outcomes within energy communities.

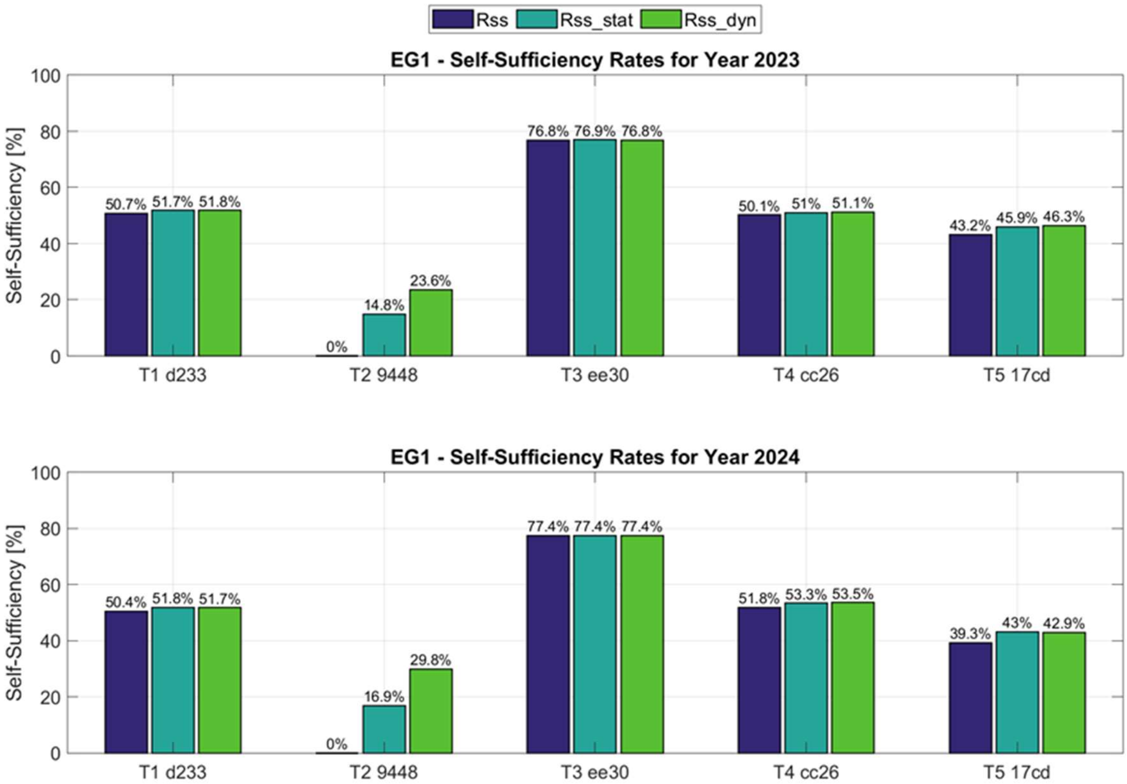

Figure 18: Self-Sufficiency Scenario 3 (T2 as Consumer) – Self-sufficiency rates (2023–2024) for Scenario 0 and Scenario 3 in Energy Community 1 (EC1), neoom testbed (T1–T5), with T2 modeled as a consumer (no PV or storage). Scenario 0 reflects individual operation (T2 operating independently, labeled Rss). Scenario 3 shows T2 as part of the Energy Community EC1 under static (Rss_stat) and dynamic (Rss_dyn) allocation. The results highlight the substantial self-sufficiency gains enabled by dynamic allocation for a non-generating member—rising from 0% to nearly 30%—achieved solely through internal sharing without additional infrastructure (FHTW).

6.3.2.2 Static vs. Dynamic Energy Allocation Methods

The empirical results underscore the practical differences between static and dynamic allocation methods when applied to real-world energy communities. As shown in Section 6.3.2.1, improvements in self-sufficiency across producer-heavy communities were generally modest, particularly under static allocation, which led to only marginal increases due to limited flexibility in redistributing surplus energy.

Dynamic allocation, in contrast, offered more meaningful gains by better aligning the distribution of shared electricity with real-time consumption patterns. This effect was clearly demonstrated in Scenario 3, where testbed participant T2 was reconfigured from a prosumer to a pure consumer. Under static allocation, T2 reached a self-sufficiency level of just 16.9%, whereas dynamic allocation enabled a self-sufficiency rate of nearly 29.8% in year 2024 (see Figure 18). These results highlight the ability of dynamic allocation to significantly improve energy allocation within the EC, especially for participants without generation capacity of their own.

This case illustrates the potential value of intentional community composition. By including consumer-only members in otherwise producer-heavy configurations, communities can move toward a more balanced relationship between production and consumption, which is essential for energy allocation to operate effectively. Importantly, these gains were achieved without any additional hardware investment, making this a low-barrier strategy for improving community performance.

However, while dynamic allocation provides technical and economic advantages in many contexts, its implementation also raises governance considerations. In communities where generation assets are individually owned and roles are clearly delineated, the model is relatively straightforward to apply. In contrast, in jointly financed or co-owned systems, dynamic allocation may raise concerns about fairness—particularly if energy distribution disproportionately benefits members with higher or more optimally timed consumption, despite equal financial contributions.

In such cases, static allocation—though less effective in maximizing the internal use of shared energy across the community—may be perceived as more equitable due to its transparent, fixed-share structure. As a result, the choice between static and dynamic models should not be based solely on performance metrics, but should also reflect the ownership models, governance arrangements, and fairness expectations of community members.

Taken together, the findings suggest that technical optimization and social acceptability must be jointly considered when selecting allocation strategies. Dynamic allocation can unlock more of the available potential in well-configured communities, but must be matched with appropriate participation structures and communication to ensure member buy-in. Continued experimentation and stakeholder engagement will be essential in refining these approaches for diverse implementation settings.

6.3.2.3 Economic Impacts

Financial outcomes varied across the testbeds, with the most significant benefits observed in configurations featuring a heterogeneous mix of participants. In particular, Scenario 3—where Testbed T2 was modeled as a consumer-only participant without photovoltaic generation or battery storage—provides a representative example of how energy community participation can reduce costs for non-generating members while also generating additional income for producing members.

Upon joining the energy community in Scenario 3, T2 experienced substantial cost reductions compared to operating independently in Scenario 0. As illustrated in Figure 19, annual electricity costs are shown for three configurations: independent operation (Scenario 0, labeled Building), community participation with static allocation (Scenario 3, labeled EC_stat), and community participation with dynamic allocation (Scenario 3, labeled EC_dyn). These labels correspond to the allocation methods used in Figure 17 and Figure 18, where the same scenarios were presented as Rss, Rss_stat, and Rss_dyn, respectively.

In 2023, participation in the energy community under the static allocation resulted in savings of approximately €1,570, or 9.04% of annual electricity costs, while the dynamic allocation yielded even greater savings of €2,503, or 14.42%. This trend continued in 2024, with cost reductions increasing to €1,762 (10.31%) under static allocation and €3,117 (18.23%) under dynamic allocation. These calculations reflect net electricity costs (or savings), based solely on energy consumption and grid tariff data. They do not account for the financing or depreciation of hardware or software infrastructure.

These results highlight the economic value of internal redistribution mechanisms, especially under dynamic allocation that match surplus generation to real-time demand. For non-generating members such as T2, participation in a well-balanced community allows access to lower-cost electricity without the need for additional investment in generation capacity.

More broadly, the findings suggest that community composition plays a critical role in maximizing economic outcomes. Effective alignment between production and consumption profiles—especially when supported by dynamic allocation—can substantially enhance the financial viability of energy communities, offering tangible benefits even to those who cannot contribute renewable generation themselves.

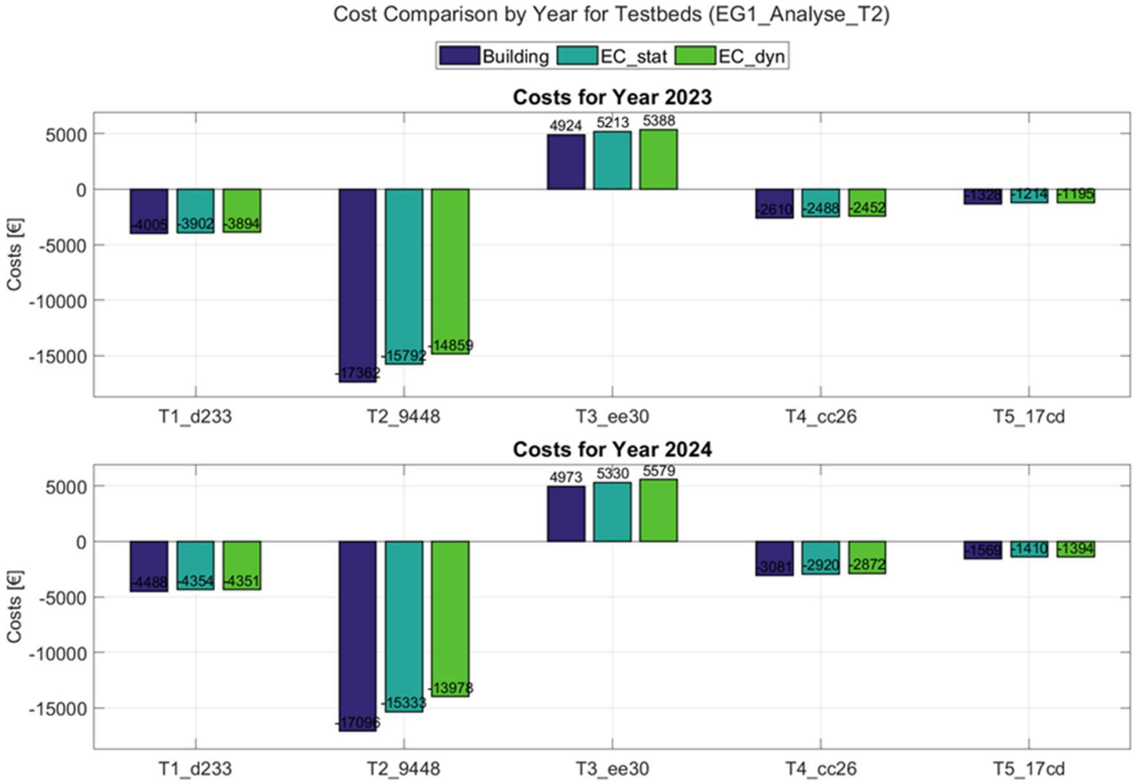

Figure 19: Annual Electricity Costs Scenario 3 (T2 as Consumer) – Annual net electricity costs (2023-2024) for T2 in Scenario 0 (independent operation) and Scenario 3 (community participation) in Energy Community 1 (EC1), neoom testbed (T1–T5). Bars represent Scenario 0 (Building, individual operation) 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).

6.3.3 Results of Baseline-Communities

In contrast to the more technology-intensive testbeds, the Baseline-Communities were implemented with minimal additional infrastructure, relying primarily on existing photovoltaic systems and standard smart metering setups. These communities represent simpler configurations where energy sharing is facilitated through administrative processes rather than active technical optimization. While less complex, they offer important reference points for understanding the basic functionality, legal considerations, and organizational challenges of early-stage energy communities—particularly in residential settings.

The results presented here focus on one such baseline implementation: a shared photovoltaic (PV) installation serving a multi-unit residential building (seven apartments) in Upper Austria. Designed to supply on-site solar energy to the building while feeding surplus electricity into the public grid, this site reflects one of the most straightforward forms of an energy community, based solely on PV generation and smart meter infrastructure.

Although a broader selection of Baseline-Communities had initially been planned, the dynamic nature of the project—combined with an evolving regulatory context and the practical challenges of identifying and engaging suitable participants—ultimately limited the number of implementations. Nevertheless, the selected pilot site offered a high-quality collaboration that yielded both detailed operational data and critical insights. These included legal, administrative, and organizational considerations that are essential for the successful deployment of shared energy systems in residential settings.

6.3.3.1 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 V.

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 V: 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%**

6.3.3.2 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 5.1 and the cooperative models discussed in Section 5.2. 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.

6.4 Conclusions

The testbed implementations carried out in UCERS offer valuable empirical insights into how energy communities function under different technical and organizational conditions. While the results highlight promising pathways—such as the benefits of dynamic allocation, balanced prosumer and consumer composition, and practical approaches to shared infrastructure—they also underscore the limitations that often accompany real-world research. Constraints related to data availability, participant diversity, and evolving regulatory frameworks necessarily shape the scope of findings. Nonetheless, the experiences gathered across both Tech-Communities and Baseline-Communities provide a strong foundation for further development and help inform future efforts to design scalable, inclusive, and context-sensitive models for community-based energy systems.

7 Project Key Findings

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 key surveys (Sections 3 and 4), the development and testing of digital platforms (Section 5), and a set of real-world testbeds (Section 6). Together, these efforts offer a multi-dimensional view of the opportunities and challenges that characterize the emerging EC sector in Austria.

7.1 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.

7.2 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 4). 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 fulfillment 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.

7.3 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.

7.4 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. See Figure 11 to Figure 16.

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.

7.5 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.

7.6 Conclusion

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.

The next section builds directly on these findings, translating empirical insights into actionable recommendations. It outlines strategic interventions to support EC scalability, equity, and long-term impact—ensuring ECs continue to evolve as resilient and inclusive actors in Austria's energy transition.

8 Recommendations and Future Perspectives

Drawing on the findings presented in Section 7, this section offers strategic recommendations to support the continued development of energy communities (EC) in Austria. 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.

8.1 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 (Section 3) and later, more self-directed ECs evaluated through a national sustainability evaluation scheme (Section 4) highlight both the diversity of experiences and the structural shifts occurring across the sector.

8.2 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.

8.3 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.

8.4 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.

8.5 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 behavioral 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 behaviors. Research funding should prioritize predictive control, decentralized optimization, and cross-sectoral energy integration.

8.6 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.

8.7 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.

8.8 Further Information

For inquiries related to the results presented in Section 6 contact:

- Matthew Clarke matthew.clarke@technikum-wien.at

For inquiries related to the results presented in Section 4 contact:

- Natalie Taupe natalie.taupe@technikum-wien.at

For general questions about the project, please contact Matthew Clarke.

Please begin the subject line of your email with **[UCERS]** to aid in processing your request.

9 Appendices

9.1 Appendix A: Overview of Survey and Interview Methods

To better understand the perspectives, needs, and experiences of those involved in energy communities (EC), the UCERS project implemented a multi-method research approach combining both quantitative and qualitative data collection. The focus was placed on two key stakeholder groups: end-users, including current or prospective EC members and interested citizens; and EC operators, such as community founders, administrators, and technical service providers. All research activities were grounded in a review of existing literature on energy community participation and aimed at identifying both the social and operational dimensions relevant to EC design and digitalization. The insights gained through these activities directly informed the development of the UCERS Community Data Exchange Platform and related tools, ensuring that these reflect real-world needs and expectations. Additional information on the studies conducted, as well as the literature consulted, can be found in Deliverable D2.1 and is available upon request.

9.1.1 Quantitative Survey of Members and Prospective Members

A quantitative online survey was distributed via project partner neoom to members of existing neoom-affiliated ECs and individuals who had expressed interest in joining a future EC. The survey was open between December 2023 and February 2024 and included two reminder rounds. Out of approximately 1,000 contacted individuals, 174 completed the survey—127 were current EC members, and 47 were prospective members.

The survey covered the following areas:

- User feedback on neoom's KLUUB platform
- Experiences within ECs (members only)
- Expectations regarding future EC development
- Perceptions of social values within ECs
- Socio-demographic information

The respondent group was not demographically balanced. The majority (94%) identified as male, and 92% lived in owner-occupied homes, indicating a high degree of residential stability. Most respondents (85%) described their environment as rural or semi-rural. In terms of age, the distribution was relatively even, though participation was lower among individuals under 30 and over 70 (Figure 20). Educational attainment skewed toward higher levels, with those holding only compulsory education significantly underrepresented (Figure 21). In addition, households with incomes above the national median were overrepresented. These characteristics reflect a profile consistent with early adopters and likely influenced respondents' perspectives on energy communities.

It is important to note that these patterns reflect the characteristics of those who chose to respond to the survey, not a deliberate selection on the part of the study design. While efforts were made to ensure broad accessibility and inclusivity in survey distribution, participation remained skewed toward particular demographic groups.

Regarding energy behavior, 25% of participants identified as prosumers—those who both produce and consume electricity—while the remaining 75% were consumers only. This distribution highlights the varied roles individuals currently play within ECs.

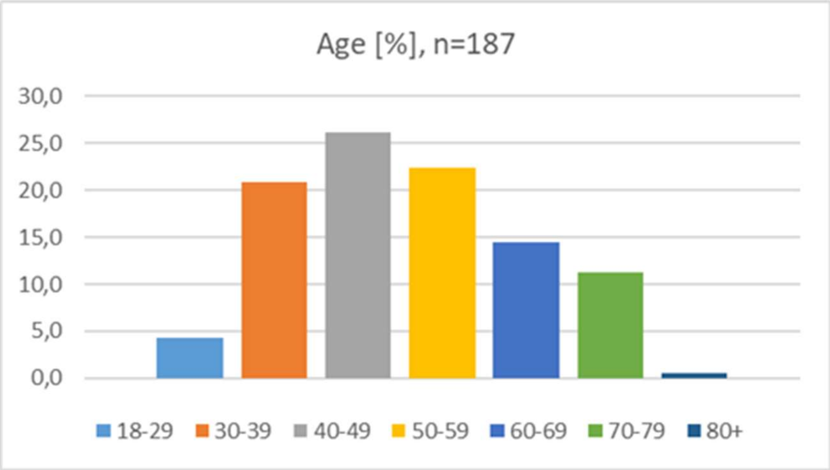

Figure 20: Age Distribution of Sample (FHTW).

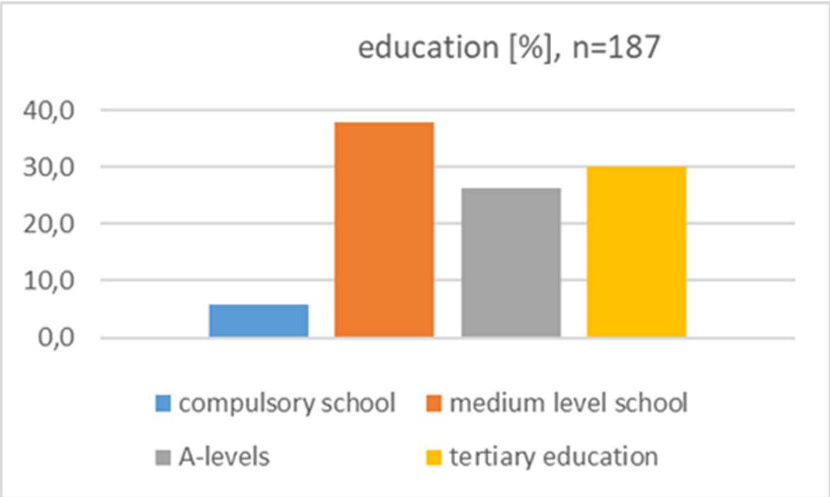

Figure 21: Education Levels in Sample (FHTW).

9.1.2 In-Depth Interviews with EC Members

To supplement the survey data, six qualitative interviews were conducted in June 2024 with selected participants from the survey pool. These interviews were held via Zoom and lasted approximately 30 minutes each. The interview guideline focused on:

- Participants' experiences with community-building in ECs
- Perceived social added value
- Expectations for future participation

The interviews offered qualitative insights into motivations, community dynamics, and perceived obstacles or benefits, helping contextualize survey findings.

9.1.3 Stakeholder Interviews: EC Establishment and Operation

Prior to the member survey and follow-up interviews described in Sections 9.1.1 and 9.1.2, several semi-structured interviews were conducted in July and August of 2023 with energy community (EC) founders and operators. The aim was to gain insights into the challenges faced during both the establishment and ongoing operation of ECs. Key topics addressed in these interviews included:

- Legal form, size, and structure of the EC
- Recruitment of members and internal decision-making
- Administrative and technical challenges
- Member engagement and satisfaction

Interviews were transcribed and analyzed using qualitative content analysis (MaxQDA). An overview of interviewees is provided in Table VI.

Table VI: Stakeholder Interviews: EC Establishment - Overview of stakeholder interviews on EC establishment and operation (FHTW).

Ref.	Date	Position of Interviewee
Interviewee 1	26.07.2023	Initiator chairman of one EC
Interviewee 2	27.07.2023	Operator of full-service platform for ECs
Interviewee 3	02.08.2023	Initiator and manager of ECs
Interviewee 4	23.08.2023	Operating manager of 2 ECs
Interviewee 5	29.08.2023	Expert of full-service provider, responsible for EC administration

9.1.4 Stakeholder Interviews: Digitalization of ECs

To examine the current use and future potential of digital tools in ECs, additional expert interviews were conducted in August and September 2023. Participants were selected based on their direct involvement with digital services for ECs, either as developers or users.

The interviews covered:

- Digital tools used during EC founding and operation.
- Challenges related to digital integration (e.g. legal, financial, and data security).
- Benefits of digital tools, such as transparency, automation, and load management.

As with the operational interviews, transcripts were analyzed using qualitative content analysis. Table VII summarizes the interviewees.

Table VII: Stakeholder Interviews: EC Digitalization - Overview of stakeholder interviews on digitalization of ECs (FHTW).

Ref.	Date	Position of interviewee
Interviewee 6	10.08.2023	Project leader of an energy community
Interviewee 7	24.08.2023	Technical project manager within EC software service
Interviewee 8	01.09.2023	Product manager for digital business models for EC
Interviewee 9	04.09.2023	Representative of digital technology service provider
Interviewee 10	04.09.2023	Representative of software/hardware developer for EC

9.2 Appendix B: Evaluation Scheme

9.2.1 Description of the Categories and Criteria

Ecology and Health	Energy Consumption	Proportion of Renewable Energy	Eco-Design of Equipment	Environmental Protection and Biodiversity	Protection of the Visual Landscape
Self-Sufficiency and Supply Security	Self Sufficiency Rate	Contribution to Grid Stability	Security of Supply	Local / Regional Energy Generation	
Affordable Energy & Economic Viability	Energy Prices	Economic Viability			
Regional Development	Regional Value Creation	Public-benefit Investments	Regional Cooperation	Community Activities	
Education & Research	Awareness-Raising	Educational Opportunities	Research and Knowledge Exchange		
Equal Opportunity & Inclusive Processes	Inclusion and Participation	Transparent Processes	User-Friendly Procedures		
Community Benefit	Member Satisfaction & Quality of Life				

For the reader's convenience, Figure 6 from Section 4.4.4 is reproduced above. The following section provides a more detailed description of the evaluation scheme's seven categories and their associated criteria, including the rationale and definitions used during development.

Category 1: Ecology and Health

This category considers the sustainable use of renewable and non-renewable resources, thus contributing to the protection of human health through environmental protection. By applying the precautionary principle (Calliess, 2013) the future availability of ecosystem functions and biodiversity should be safeguarded. Similarly, landscape areas of particular character and beauty should be protected.

Criterion 1.1. Energy Consumption

Definition: This criterion assesses the change in energy consumption of individual members of an energy community since their membership. It analyzes how conscious energy use, changed behaviors, and adjusted habits have contributed to a reduction or adjustment in energy consumption.

Description:

Energy demand in society is increasing, especially as more analogue items are being replaced by digital alternatives. Therefore, the EU has set a goal to reduce final energy consumption by at least 11.7% compared to the expected energy demand in 2030 (European Commission, 2025b). Energy consumption can thus be seen as a key factor for the ecological (and economic) sustainability of energy communities. In addition to technological efficiency measures, the concept of sufficiency plays a crucial role (Gährs et al., 2022). While efficiency refers to the technical improvement of devices, sufficiency involves the fundamental reduction of energy demand, for example, through control, behavioral changes, or more conscious consumption. Studies have shown that participation in an energy community can motivate members to critically review, adjust, and reduce their energy consumption (Mura et al., 2025).

Positive direction for sustainable development: In terms of sustainability, the reduction of energy consumption, or at least more conscious energy use, is considered a positive development.

Criterion 1.2. Proportion of Renewable Energy

Definition: Proportion of renewable energy generation within the energy community.

Beschreibung: One of the overarching goals of energy communities is the expansion of renewable energy. In 2023, renewable energy accounted for 24.5% of energy consumption in the EU (eurostat, 2024). The EU has set a target to increase this share to 42.5% by 2030, with the goal of reaching 45% (European Commission, 2025c).

This criterion assesses the percentage of renewable energy in the total electricity generation within the energy community. The relevance of this criterion arises from the need to minimize the use of fossil fuels and reduce greenhouse gas emissions.

Note: This criterion is primarily relevant for CECs, as RECs are, by definition, already based on renewable energy sources.

Positive direction for sustainable development: The focus of this category is on achieving the highest possible proportion of renewable electricity generation.

Criterion 1.3. Eco-design of Equipment (Generation and Consumption Devices)

Definition**:** Consideration of eco-design aspects when purchasing generation equipment and consumption devices within the energy community.

Description: The generation and use of energy within an energy community requires systems and devices (generation equipment and consumption devices) whose entire lifecycle is associated with resource and energy consumption. This includes all phases of the lifecycle, from raw material extraction to manufacturing, assembly, operation, maintenance, and finally, reuse, recycling, or disposal. Considering these life cycle phases is critical to the success of the energy transition (Reindl and Dalhammar, 2024). Each of these phases generates emissions into water, air, and soil, which can pose environmental and health risks. The new Eco-design Regulation (ESPR, 2024) sets requirements for sustainable product design. By intentionally designing generation and consumption devices, negative environmental impacts can be reduced. Circular economy strategies provide effective solutions (BMK, 2022), including: sharing and collective use of equipment, simple maintenance processes to extend the lifespan, processes and business models for the reuse and refurbishment of components, and efficient recycling processes to recover valuable materials. Additionally, the critical and conflict minerals should be avoided. Critical minerals have limited availability and high economic significance (Lyhs, 2022), while conflict minerals originate from conflict or high-risk areas (Taylor, 2024).

Positive direction for sustainable development: Energy community members consider longevity and resource conservation (circularity) when purchasing equipment and hereby contributing to sustainable development.

Criterion 1.4. Environmental Protection and Preservation of Biodiversity

Definition: The establishment and operation of generation facilities can impact nature conservation goals, such as protecting ecosystems and the preservation of biodiversity. This criterion evaluates to what extent energy communities minimize negative environmental impacts and implement appropriate protection measures.

Description: The use of land for generation facilities can present various ecological challenges. Key environmental aspects include land use and potential land sealing, threats to species and habitats, disturbances to flora and fauna, and emissions such as noise, odors, and fine dust, which can negatively affect environmental quality and living conditions (Rahadian et al., 2025). Energy communities have the opportunity to address these aspects and take actions to reduce negative environmental impacts. These measures may include prioritizing the installation of photovoltaic (PV) systems on already developed or previously disturbed sites (e.g., rooftops, Agri-PV), selecting sites with minimal environmental impact for new installations, bird protection measures such as markings on wind turbines, or intelligent turbine shutdowns, using organic waste instead of primary biomass for energy production, and supporting renaturation or greening efforts.

Positive direction for sustainable development: Measures to protect ecosystems and biodiversity are discussed and implemented. These aspects can be reflected upon in discussions within the energy community and systematically considered when planning new installations.

Criterion 1.5. Protection of the Visual Landscape

Definition: The establishment and operation of generation facilities can also impact the protection of the visual landscape. This criterion assesses to what extent energy communities incorporate this factor into their decision-making processes.

Description: Renewable energy infrastructures are closely linked to transforming the landscape, which can impact the perceived quality of the landscape and local acceptance. Landscape considerations are essential in spatial energy planning, which typically takes into account environmental, cultural, and ecological needs. However, it often overlooks the community's perception of the landscape, including both the physical alterations and the meanings associated with them (Codemo et al., 2024). Energy communities have the opportunity to integrate landscape considerations into their decision-making processes.

Positive direction for sustainable development: Landscape considerations are included into decision-making processes. These aspects can be discussed within the energy community and systematically addressed when planning new installations.

Category 2: Self-Sufficiency and Supply Security

This category encompasses two central aspects: energy supply independence and ensuring the basic supply for members. High self-sufficiency and measures to ensure supply security help reduce external dependencies, stabilize energy costs in the long term, and increase resilience against external supply risks.

Criterion 2.1. Self-Sufficiency Rate

Definition: This criterion assesses whether energy communities set a target for their self-sufficiency rate and how effectively this target is achieved. The self-sufficiency rate represents the proportion of the total electricity consumption of an energy community that is met by its own generation within the community. It is calculated as follows:

Self-sufficiency rate = Energy drawn from the energy community / Total consumption (%)

Description: A key goal of energy communities (particularly RECs) is to consume the energy generated locally within the community, thus reducing the need for external energy procurement. A high self-sufficiency rate reduces external dependence on international energy markets and fossil fuels, providing long-term economic benefits (Digitales Institut, 2023). However, the degree of self-sufficiency achievable in a renewable energy community depends, among other factors, on renewable energy potentials (McKenna et al., 2015), as well as the individual and collective interests of the energy community (Llewellyn et al., 2024).

Note: A high self-sufficiency rate can be achieved through targeted load management within the energy community, where the generation and consumption of members are best coordinated to optimize local or regional energy supply. This involves shifting generation peaks to low-production times (e.g., via storage systems) and consumption peaks to high-production times (either through conscious usage behavior or automated control systems).

The criteria for Self-Sufficiency (2.1) and Grid Stability (2.2) pursue similar goals but differ in their focus. While the Self-Sufficiency criterion focuses on the objectives and the level of self-sufficiency achieved, the Grid Stability criterion evaluates the specific measures implemented that contribute to relieving and stabilizing the electricity grid.

Positive direction for sustainable development: The potential for self-sufficiency is reflected upon within the energy community's discussions, and goals are set based on these reflections.

Criterion 2.2. Contribution to Grid Stability

Definition: This criterion evaluates the extent to which energy communities contribute to stabilizing the electricity grid through grid-supportive measures, thereby preventing critical grid situations, bottlenecks, and overloads, and ensuring supply quality.

Description: Energy communities have the potential to actively support the electricity grid by creating flexible, decentralized generation and consumption structures (Preßmair et al., 2024). Key aspects of grid supportiveness include the avoidance of peak loads and bottlenecks (Velini et al., 2025). A high complementarity of various renewable energy sources (e.g., photovoltaics, wind power, hydropower, biomass) can compensate for generation fluctuations and thus contribute to grid stability (Chowdhury et al., 2025). Furthermore, flexible consumption strategies, such as intelligent load management (Panda et al., 2023) or sector coupling with heating and mobility applications (Košnjek et al., 2024), enable targeted demand adjustment to match the volatile supply. The use of storage systems also plays an important role by temporarily storing generation surpluses and releasing them according to demand (Pasqui et al., 2025).

Positive direction for sustainable development: Implementation of grid-supportive measures to stabilize the electricity grid and ensure supply quality.

Criterion 2.3. Security of Supply

Definition: The ability of an energy community to ensure energy supply even under deviating or critical conditions.

Description: Supply security is a central element of a resilient and sustainable energy supply. Power outages pose varying risks to different stakeholders (Mutani et al., 2021). Energy communities can enhance their independence and stability against external influences such as grid failures, supply fluctuations, or extreme weather events through various measures. Examples of such measures include the integration of storage systems, such as battery storage or thermal storage, to secure energy supply during periods of low generation, as well as other emergency and backup systems to maintain islanding capabilities or alternative energy sources for crisis situations.

Positive direction for sustainable development: Presence of precautionary measures.

Criterion 2.4. Local and Regional Energy Generation

Definition: The share of energy generated locally or regionally.

Description: Local and regional energy generation forms the basis for spatial proximity between generation, storage, and consumption. This proximity can improve the efficiency and stability of the energy system by reducing grid losses and strengthening supply security (He et al., 2025). Using energy where it is produced enhances the overall resilience and efficiency of the system (Dworatzek et al., 2025).

Note: According to the Renewable Expansion Act (EAG), local renewable energy communities are defined as groups whose members are connected to the electricity grid within the same transformer (NE 6-7) area. Regional renewable energy communities, on the other hand, are typically connected to a single substation (NE 4-5). Citizen energy communities have no proximity limitations.

Note: This criterion is relevant in the Austrian context and applies primarily to BEGs, as proximity requirements based on grid topology are already legally defined for EEGs. Proximity requirements in other countries may vary.

Positive direction for sustainable development: Maximizing the share of locally or regionally generated energy.

Category 3: Affordable Energy and Economic Viability

This category addresses affordable basic energy supply and the economic sustainability of the energy community. Energy costs must remain affordable for all members while ensuring the long-term financial viability of the community.

Criterion 3.1. Energy Prices

Definition: Designing affordable energy prices for all members of the energy community, with particular consideration for households affected by energy poverty.

Description: This criterion focuses on the financial affordability of energy prices (in this case, electricity prices) for all members. Energy communities have diverse options for structuring tariffs that can be tailored to the specific needs and values of their members (Koordinationsstelle, 2023). Renewable energy communities benefit from reduced grid tariffs and levies, contributing to lower energy costs. Additional savings potentials arise from load management, targeted energy efficiency measures, and promoting more conscious energy consumption behavior (Preßmair et al., 2024). Energy communities can induce behavioral changes by influencing members' education, beliefs, values, attitudes, and habits (Anda and Temmen, 2014; Simoiu et al., 2022). Such changes enable conscious energy and cost savings (Felice et al., 2022). Socially-just pricing also requires targeted support for low-income households (van Bommel and Höffken, 2021). Measures such as special tariffs, electricity donations, or compensation mechanisms can contribute here.

Positive direction for sustainable development: Energy prices are affordable for members and are below or within the range of market-standard tariffs. The design of price structures for individual members requires joint 7 within the energy community.

Criterion 3.2. Economic Viability (of the Energy Community)

Definition: Assessment of the economic sustainability of the energy community throughout its establishment, operation, and further development.

Description: A fundamental prerequisite for the founding and long-term sustainability of an energy community is its economic stability. In particular, RECs are designed to be non-profit oriented (Koordinationsstelle, 2022). In contrast, CECs may pursue commercial interests. For RECs, economic viability does not mean maximizing profits but rather achieving cost-covering operations, that is, avoiding deficits and “breaking even.” Revenues from feed-in tariffs, self-consumption, or service offerings should be sufficient to cover ongoing costs (e.g., operation, maintenance, administration) and build reserves for future investments.

Positive direction for sustainable development: The energy community is financially stable and sustainable in the long term.

Category 4: Regional Development

This category addresses the contribution of energy communities to the development of their respective regions. The focus extends beyond the economic dimension to include the social and cultural added value generated by local embedding.

Specifically, the category encompasses the following aspects:

- Independent livelihoods through regional value creation, securing and creating (qualified) jobs locally, strengthening small-scale economic actors, and curbing outmigration.
- Sustainable development of physical, human, and knowledge capital, for example through (non-profit) investments in regional infrastructure, preservation of service, supply, and social infrastructure, as well as knowledge exchange and promotion of decentralized decision-making competence by enabling tangible and direct experience of one's actions.
- Preservation of cultural heritage and cultural diversity, e.g., by supporting community-oriented structures and strengthening social resources such as a sense of community, solidarity, and participation within the region.

Criterion 4.1. Regional Value Creation

Definition: This criterion evaluates the economic contribution of energy communities to regional development, particularly regarding local contracting, strengthening regional enterprises, job creation, and fostering entrepreneurial activities.

Description: The decentralized energy transition offers potential to strengthen regional value creation, especially through locally anchored private economic activities and the creation of qualified jobs on site (Ma and Wang, 2025). Energy communities can actively support the regional economy through investments in infrastructure, procurement of regional services, and inclusion of local actors. Both direct effects (e.g., employment, contracting) and indirect impulses (e.g., company formation, skill development, innovation incentives) play a role.

Positive direction for sustainable development: The energy community makes a measurable contribution to regional value creation by preferentially cooperating with local businesses, creating jobs, or activating regional innovation potential.

Criterion 4.2. Public-Benefit Investments

Definition: Commitment of public-benefit investments by the energy community to strengthen the common good and regional infrastructure.

Description: Public-benefit investments originating from an energy community extend beyond mere energy generation. They enhance decentralized decision-making capacities, create shared spaces for community involvement, and promote the tangible experience of individual agency. Through such investments, energy communities can contribute to the maintenance and development of service, supply, and social infrastructure. See practical example: Energy Community Schnifis (Schnifis, 2022).

Positive direction for sustainable development: To be clarified dependent on existing infrastructure.

Criterion 4.3. Regional Cooperation

Definition: This criterion encompasses both internal networking among members of the energy community (e.g., exchange formats, transparency, joint learning) and external networking with other energy communities, municipalities, regional businesses, academic institutions, and other relevant stakeholders.

Description: The sustainable development of knowledge depends fundamentally on active knowledge exchange. An energy community can be understood as a social and cooperative alliance of actors who not only produce and consume energy but also actively network, exchange information, and co-develop solutions (Campos and Marín-González, 2020). The goal is to foster synergies, knowledge sharing, and regional cooperation to enable not only technical but also social and organizational innovations.

Positive direction for sustainable development: To be clarified through discourse.

Criterion 4.4. Community Activities

Definition: The energy community initiates further community activities (e.g., mobility sharing concepts).

Description: Building on the community spirit, energy communities can foster additional activities such as sharing schemes, regular meetups, or environmental initiatives like litter collection (Koordinationsstelle, 2024). These activities enhance social cohesion, strengthen a collective sense of responsibility, and broaden the role of the energy community as a local actor for sustainability.

Positive direction for sustainable development: To be clarified through discourse.

Category 5: Education and Research

Education and research are essential foundations for maintaining the capacity for development and action, both of which are critical to sustainable development.

Criterion 5.1. Awareness Raising

Definition: This criterion evaluates the extent to which an energy community contributes to increasing its members' interest in and awareness of key topics such as sustainability, energy consumption, and systemic changes in the energy sector.

Description: This criterion assesses the community's role in enhancing both individual and collective awareness of energy, sustainability, circular economy, and systemic transformations. The focus lies on information dissemination as well as active engagement with relevant topics within the community. This can occur through communication channels (e.g., email lists, group chats), member meetings, workshops, or informal discussion rounds. Furthermore, it captures whether participation in the energy community has subjectively increased members' understanding of energy and sustainability issues and positively influenced social factors such as trust and acceptance of systemic changes.

Positive direction for sustainable development: To be clarified individually through discourse.

Criterion 5.2. Educational Opportunities

Definition: Availability and financing of initial and continuing education and training, including legal basics, operation and maintenance of installations, consulting on energy and climate topics, as well as education for local decision-makers.

Description: This criterion evaluates the extent to which educational and training opportunities exist, are utilized, and promoted within the energy community to strengthen members' competencies in the areas of energy, sustainability, law, management, and environment. The focus lies both on individual qualification of members and on building knowledge that benefits the operation and further development of the energy community. Additionally, it assesses whether local decision-makers or committed individuals with energy awareness are specifically supported or involved to anchor competencies sustainably in the region.

Positive direction for sustainable development: Depends on the region – to be clarified individually through discourse.

Criterion 5.3. Research and Knowledge Exchange

Definition: Expansion of interdisciplinary research; documentation of newly acquired knowledge and its dissemination.

Description: This criterion assesses the extent to which an energy community actively participates in research projects, seeks exchange with scientific institutions, and contributes to the generation and dissemination of practice-relevant knowledge. Energy communities can provide valuable impulses for research and development through their specific experiences and organizational structures, for example in the fields of energy technology, user behavior, participation, or new business models. At the same time, they benefit themselves by utilizing scientific networking opportunities to access current insights and innovations.

Positive direction for sustainable development: The energy community possesses its own research capacities or is actively involved in research projects and makes acquired knowledge accessible to third parties (e.g., through reports, events, or publications).

Category 6: Equal Opportunity and Inclusive Processes

This category focuses on establishing socially just, transparent, and accessible decision-making processes within energy communities.

Criterion 6.1.: Inclusion and Participation

Definition: Frameworks and processes enabling comprehensive co-determination in the energy community, e.g., consensual energy price setting for all members; inclusive, discursive, and democratic decision-making; consideration of gender and diversity aspects.

Description: This criterion evaluates the extent to which decision-making processes within the energy community are designed to be transparent, inclusive, participatory, and diversity-aware, particularly concerning price setting, price adjustments, and organizational procedures. A core feature of democratically organized energy communities is the active involvement of members in key decisions (Palm et al., 2025). This involves not only formal voting but also ongoing discourse, early engagement of relevant stakeholders, and the social and linguistic design of processes.

Positive direction for sustainable development: Functional instruments for genuine co-determination exist. Inclusive further development of decision-making processes is planned and actively promoted.

Criterion 6.2.: Transparent Processes

Definition: Clear definition, documentation, and accessibility of processes. Definitions of responsibilities, goals, effort, and organizational procedures. Data security and cybersecurity must be ensured.

Description: This criterion assesses the extent to which the energy community provides clear, comprehensible, and accessible structures and information to its members. Transparency is a key factor for building trust, fostering participation, and ensuring acceptance, especially in community-organized energy projects (Kaiser et al., 2022).

Positive direction for sustainable development: Transparent regulations and documented processes are in place; data security and cybersecurity are ensured through appropriate technical and organizational measures.

Criterion 6.3.: User-Friendly Procedures

Definition: Easy participation opportunities in an energy community as well as low-threshold operational processes.

Description: This criterion evaluates the extent to which participation and involvement in the energy community, as well as its organizational and technical procedures, are designed to be simple, accessible, and barrier-free for all members. A low-threshold design of processes is essential to prevent social exclusion and to enable participation by broad population groups (Kaiser et al., 2022).

Positive direction for sustainable development: Participation is easily accessible to all interested individuals, and the operational procedures of the energy community are clearly structured, understandable, and barrier-free.

Category 7: Community Benefit

This category focuses on the societal benefits that an energy community provides to its members.

Criterion 7.1.: Member Satisfaction and Quality of Life

Definition: Subjective perception of improved quality of life through membership in the energy community.

Description: This criterion captures the extent to which members perceive their participation in an energy community as enriching and meaningful, contributing to an enhanced individual quality of life. Emotional, social, and identity-forming aspects are emphasized, effects that go beyond purely technical or economic benefits.

Positive direction for sustainable development: Members report high satisfaction and a noticeable improvement in their quality of life resulting from their involvement in the energy community.

9.2.2 Survey Results

This appendix provides the original the indicator-level survey results referenced in Section 4.5.1. The figures are organized according to the seven sustainability categories of the evaluation scheme and illustrate how frequently specific practices or structures were reported across all participating energy communities. While most figures correspond to an entire category, in some cases individual criteria are presented separately due to the volume of associated indicators. Each figure shows the distribution of responses to the relevant indicators. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local LEGs, REGs, and BEGs.

Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification.

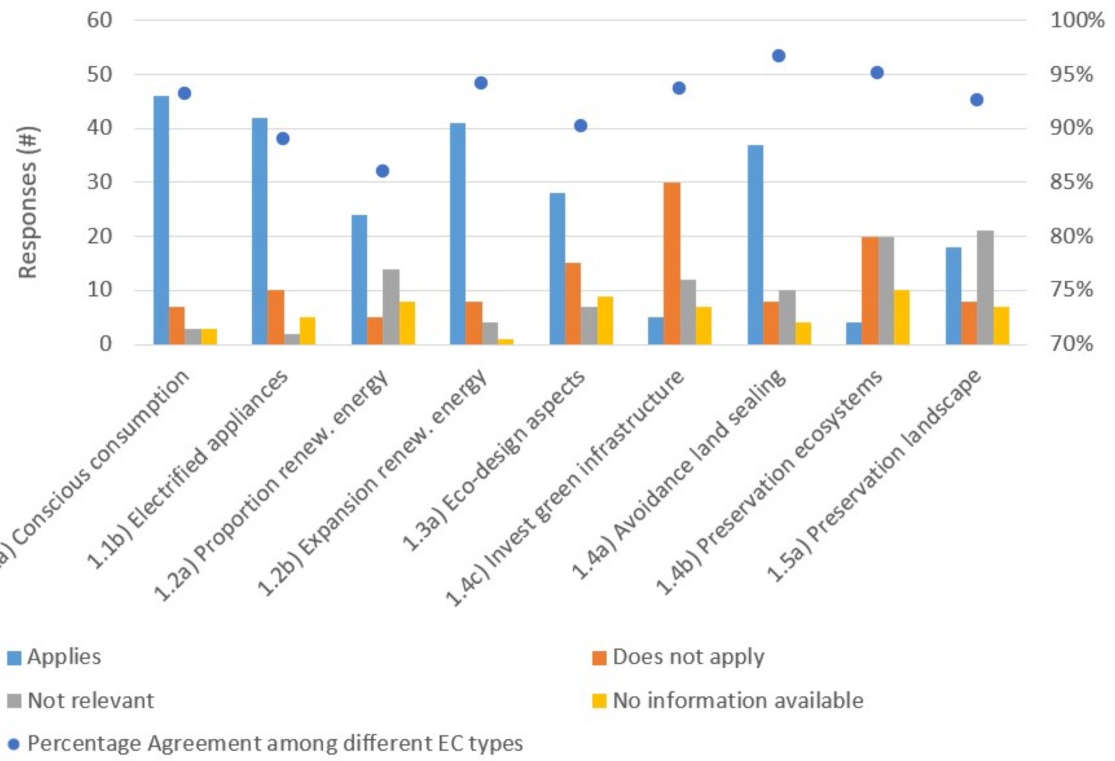

Figure 22: Survey Results: Ecology & Health - Evaluation of survey results for ***Criteria 1.1 Energy Consumption, 1.2 Proportion of Renewable Energy, 1.3 Eco-design of Equipment, 1.4 Environmental Protection and Preservation of Biodiversity, and 1.5 Preservation of the Landscape, corresponding to Category 1: Ecology and Health****. Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local RECs, regional RECs, and CECs corresponding to the Austrian legal forms LEG, REG, and BEG, respectively (FHTW).*

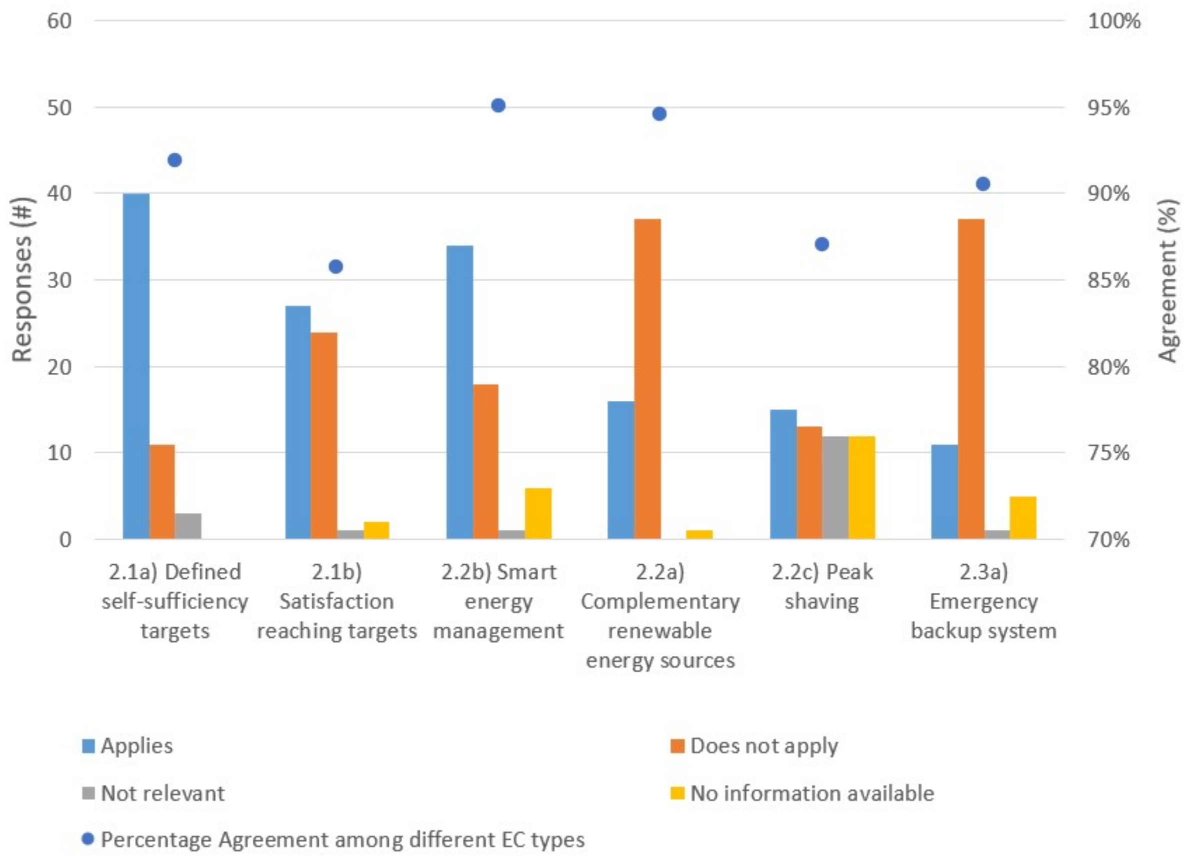

*Figure 23: Survey Results: Self-Sufficiency - Evaluation of survey results for **Criteria 2.1 Self-Sufficiency Rate, 2.2 Contribution to Grid Stability, and 2.3 Security of Supply, corresponding to Category 2: Self-Sufficiency and Supply Security**. Note that Criterion 2.4 Local and Regional Energy Generation is not shown, as it refers to the EC type and is not applicable to this type of illustration. Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local RECs, regional RECs, and CECs corresponding to the Austrian legal forms LEG, REG, and BEG, respectively (FHTW).*

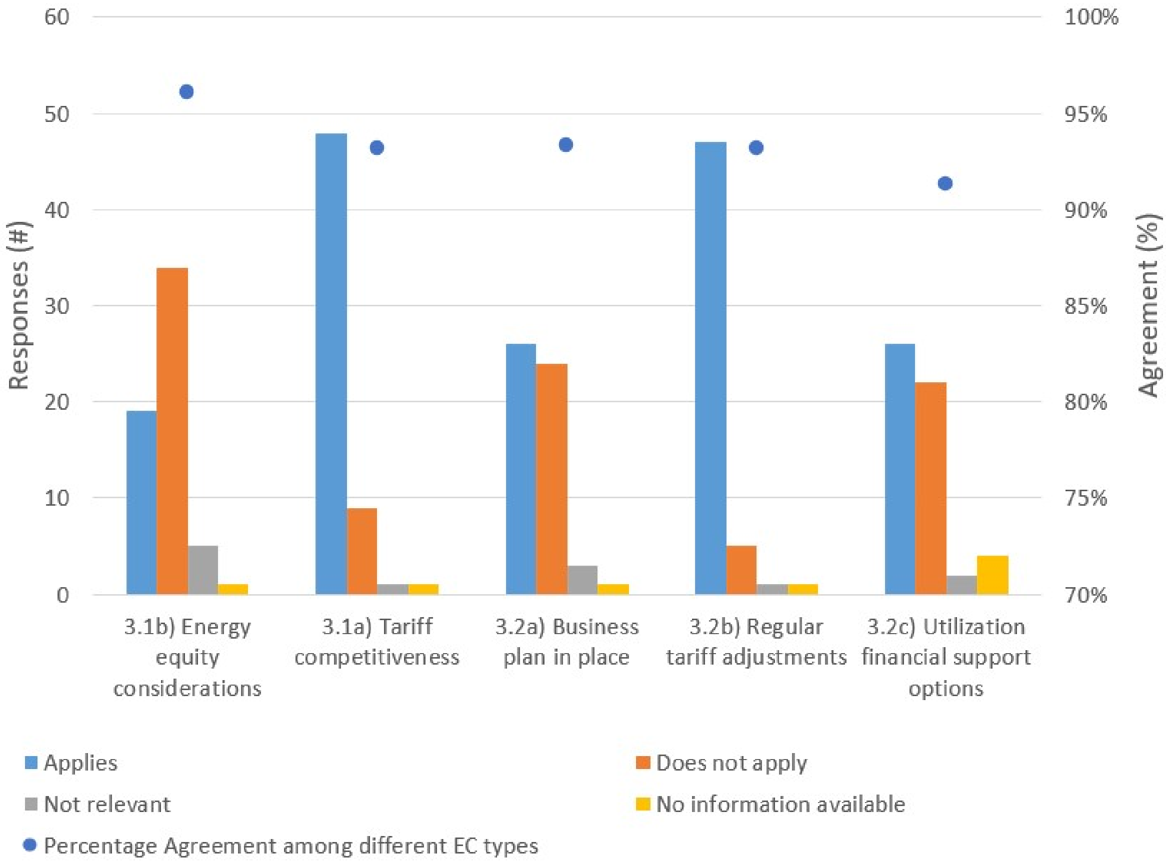

Figure 24: Survey Results: Affordability - Evaluation of survey results for ***Criteria 3.1 Energy Prices and 3.2 Economic Viability, corresponding to Category 3: Affordable Energy and Economic Viability****. Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local RECs, regional RECs, and CECs corresponding to the Austrian legal forms LEG, REG, and BEG, respectively (FHTW).*

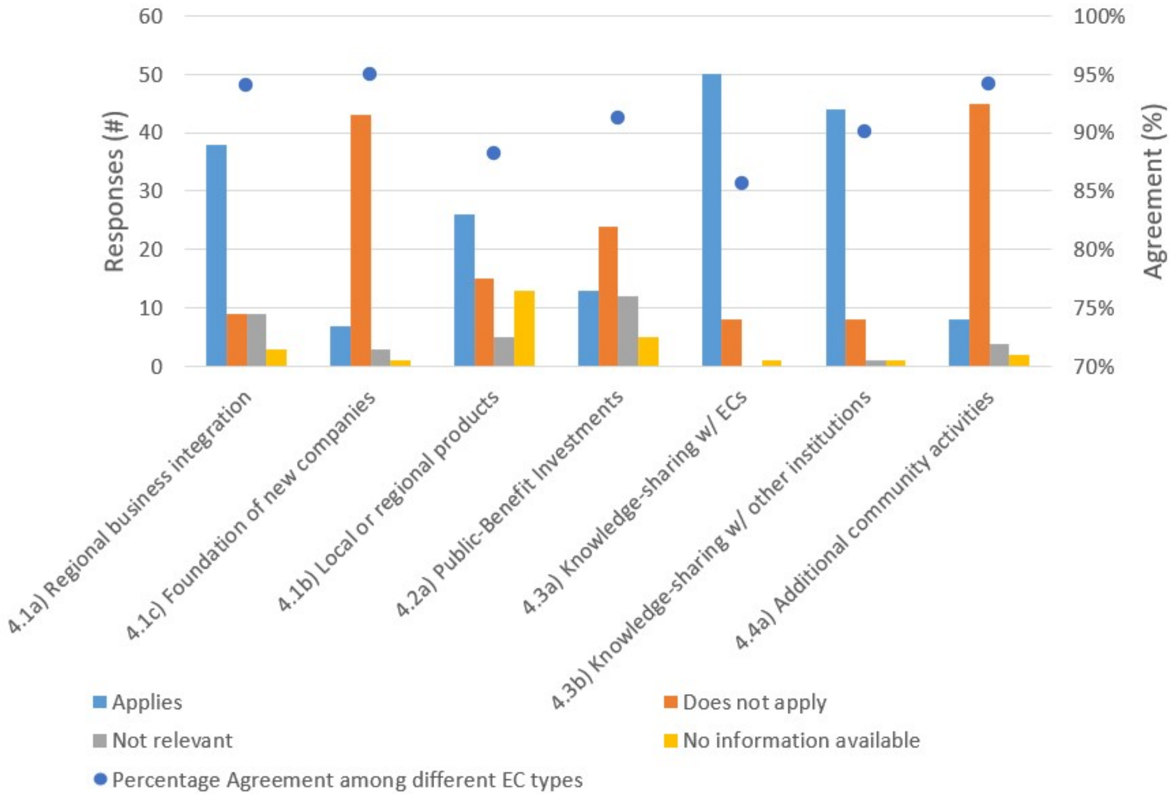

Figure 25: Survey Results: Regional Development - Evaluation of survey results for ***Criteria 4.1 Regional Value Creation, 4.2 Public-Benefit Investments, 4.3 Regional Cooperation, and 4.4 Community Activities, corresponding to Category 4: Regional Development****. Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local RECs, regional RECs, and CECs corresponding to the Austrian legal forms LEG, REG, and BEG, respectively (FHTW).*

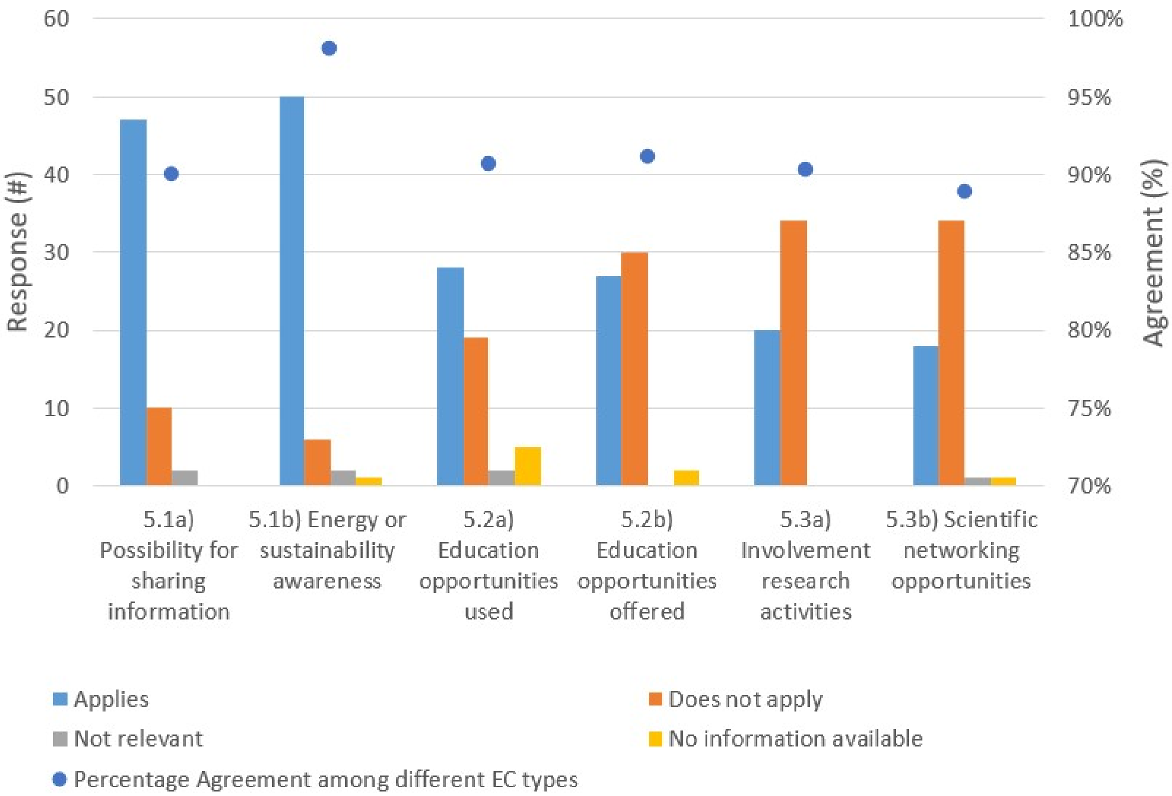

Figure 26: Survey Results: Education - Evaluation of survey results for ***Criteria 5.1 Awareness Raising, 5.2 Educational Opportunities, and 5.3 Research and Knowledge Exchange, corresponding to Category 5: Education and Research****. Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local RECs, regional RECs, and CECs corresponding to the Austrian legal forms LEG, REG, and BEG, respectively (FHTW).*

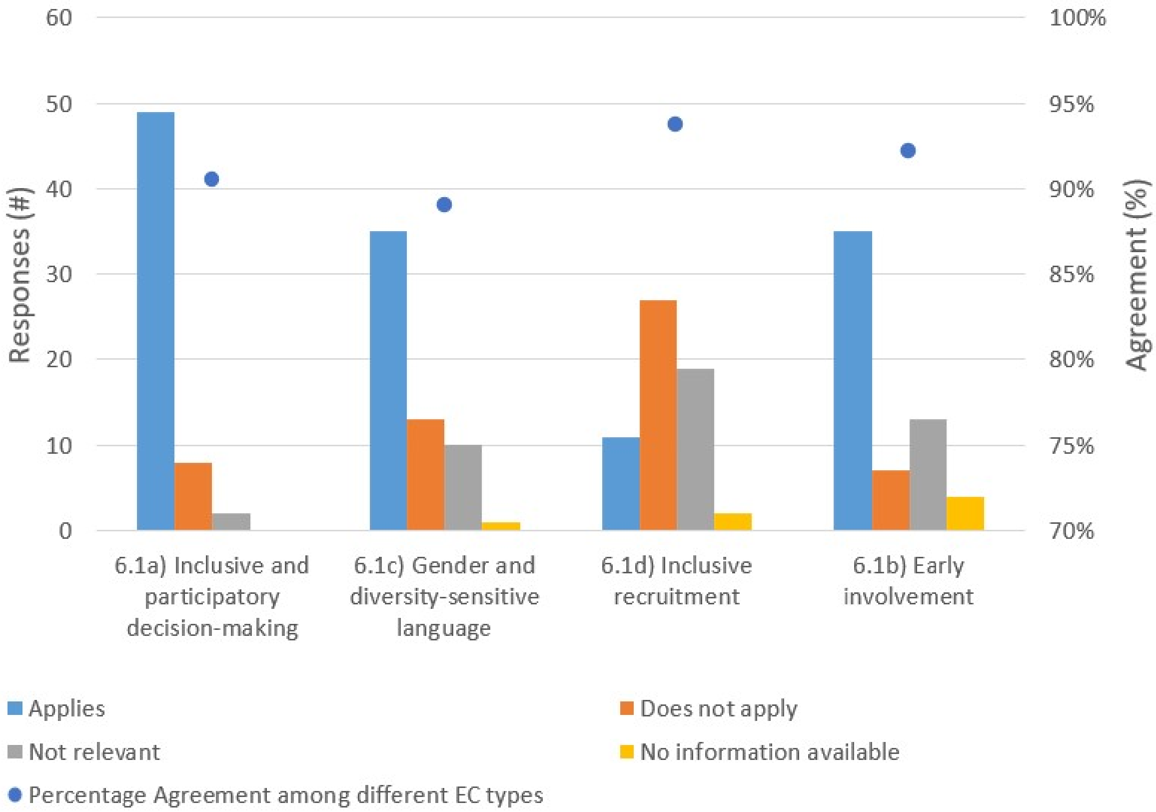

*Figure 27: Survey: Inclusive Processes - Evaluation of survey results for the **Criterion 6.1 Inclusion and Participation, corresponding to Category 6: Equal Opportunity and Inclusive Processes.** Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local RECs, regional RECs, and CECs corresponding to the Austrian legal forms LEG, REG, and BEG, respectively (FHTW).*

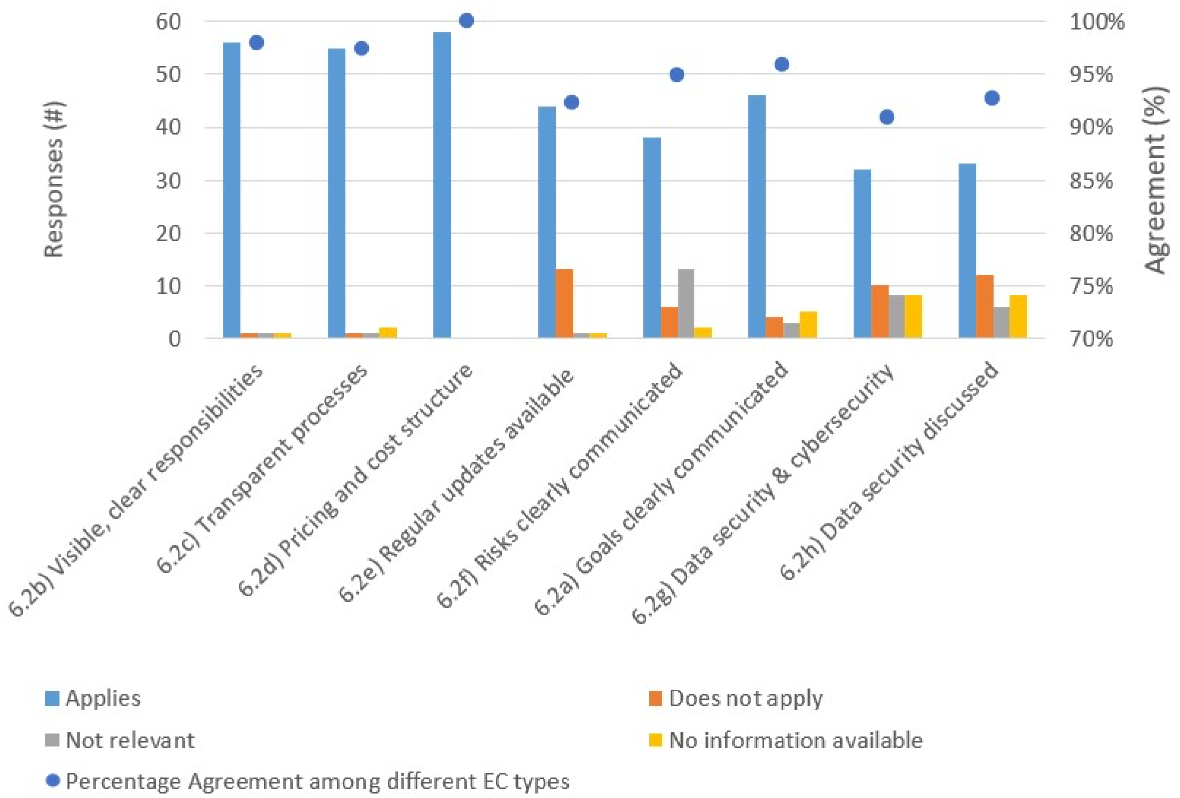

*Figure 28: Survey: Transparent Processes - Evaluation of survey results for the **Criterion 6.2 Transparent Processes, corresponding to Category 6: Equal Opportunity and Inclusive Processes**. Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local RECs, regional RECs, and CECs corresponding to the Austrian legal forms LEG, REG, and BEG, respectively (FHTW).*

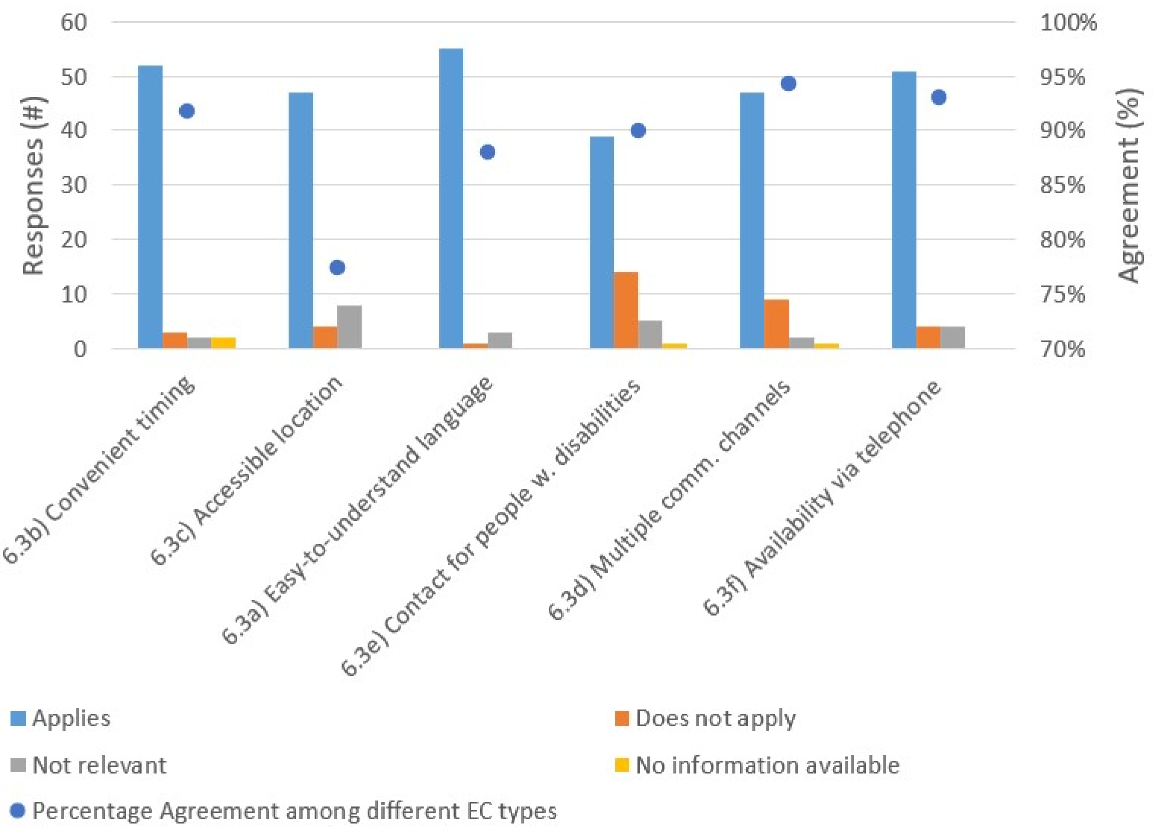

*Figure 29: Survey: User-Friendly Procedures - Evaluation of survey results for the **Criterion 6.3 User-Friendly Procedures, corresponding to Category 6: Equal Opportunity and Inclusive Processes.** Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local RECs, regional RECs, and CECs corresponding to the Austrian legal forms LEG, REG, and BEG, respectively (FHTW).*

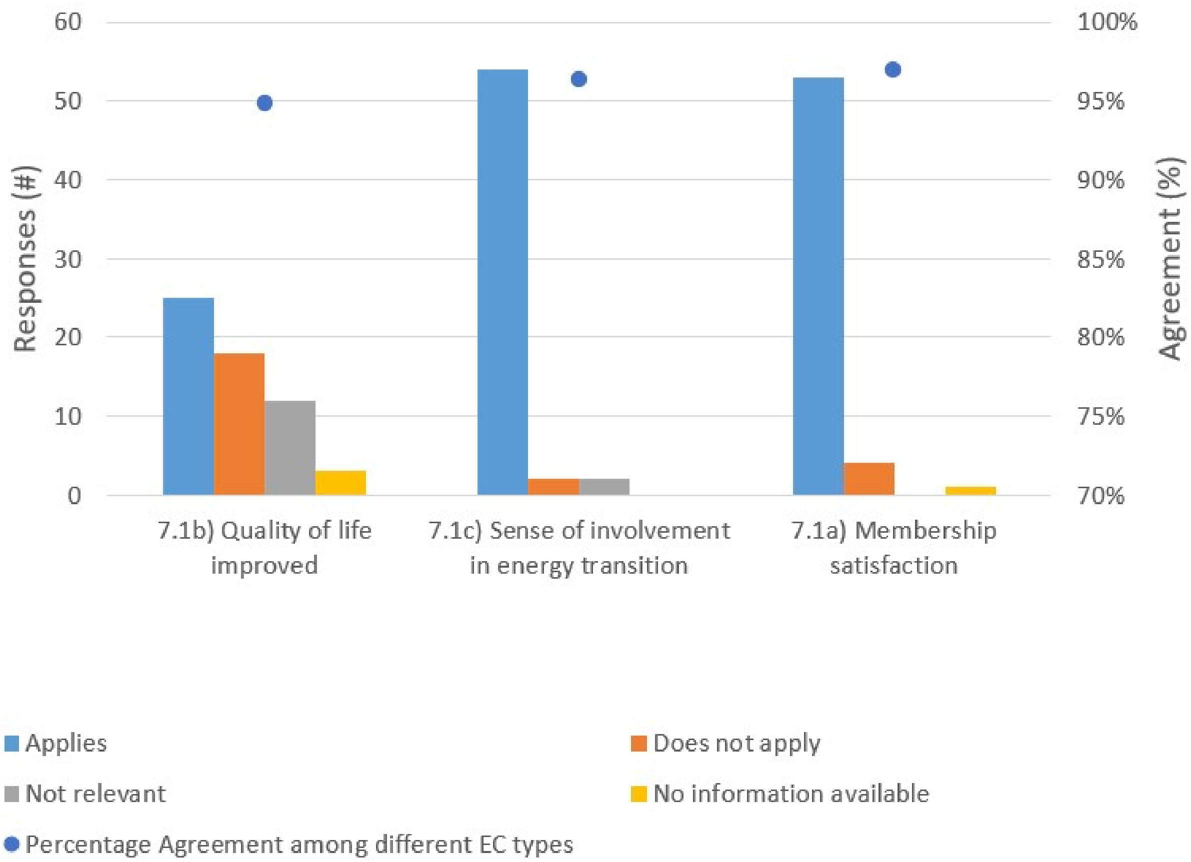

*Figure 30: Survey: Community Benefit - Evaluation of survey results for the **Criterion 7.1 Member Satisfaction and Quality of Life, corresponding to Category 7: Community Benefit**. Indicators are labeled using an ID in the format X.Yz, where X and Y (numbers) denote the category and criterion, respectively, and z (a letter) specifies the individual indicator. The sequence shown in the figure reflects post-processing groupings and may not follow a sequential order; however, each corresponds to the indicator ID listed in Table 4, Section 9.2.3. For readability, labels in the figures are presented in shortened form, and slight variations in naming may occur. In cases of uncertainty, please refer to the full indicator ID for clarification. The left axis represents the number of responses, while the right axis indicates the percentage agreement among local RECs, regional RECs, and CECs corresponding to the Austrian legal forms LEG, REG, and BEG, respectively (FHTW).*

9.2.3 Survey Tool for Energy Communities

The following survey tool is based on the evaluation scheme developed and applied within the UCERS project to assess the contribution of energy communities to sustainable development. It closely follows the structure of the original instrument used for the national survey (see Section 4.4.5), with only minor adjustments made to accommodate the English translation and to enhance clarity for the context of this public report. The original version, developed in German, can be made available upon request. Illustrations and graphics courtesy of Fachhochschule Technikum Wien.

How does my energy community contribute to sustainable development?

This evaluation scheme was developed within the UCERS project (User-Centered Solutions for Digital and Sustainable Energy Communities), funded by the Austrian Research Promotion Agency (FFG), in collaboration with experts and practitioners from energy communities. Its purpose is to help energy communities better understand where they are currently contributing to sustainable development and which of their processes are already aligned with sustainability goals. Based on these insights, communities can identify priorities and guide their further development.

The evaluation process is structured around categories (topics) and criteria (target areas), as shown in Table 1 and illustrated in Figure C1. Each criterion is linked to one or more specific questions, listed in Table 4, which make the criteria measurable and serve as the basis for assessing how well a community is performing in each category. In Table 4, the labels **Board** and **Participant** refer to individuals' roles within the energy community: **Board** indicates those responsible for organization, administration, or technical oversight, while **Participant** refers to members not involved in formal leadership or operational tasks.

To conduct the assessment, it is recommended to count the number of questions in Table 4 answered with “applies” (A) and divide this by the total number of applicable questions (B), excluding any responses marked as “not relevant” or “no information available” (C). The result for each category, calculated as A / (B – C), indicates the degree of fulfilment (ranging from 0 to 1) and is reported in Table 1. These values can also be visualized in the radar chart (Figure C2) to provide an overview of the community’s implementation status. Responses marked as “not relevant” or “no information available” are excluded to avoid unfairly lowering the fulfilment score for criteria that may not apply to all energy communities.

In parallel, Table 2 allows energy communities to rate the perceived importance of each category on a scale from 1 (very low) to 5 (very high). This self-assessment is then converted into a percentage by dividing the rating by 5. These importance ratings can also be plotted on the radar chart in Figure C2, enabling a direct comparison between how important a category is considered and how well it is currently being fulfilled. This visual comparison supports informed goal setting and prioritization.

The purpose of this evaluation scheme is not to achieve equal fulfilment across all areas but to help each community identify what is most relevant to them and understand how they can strengthen their contribution to sustainable development. It also supports reflection on potential trade-offs between goals, such as:

- The proximity criterion for renewable energy communities may restrict the use of multiple renewable energy sources (e.g., solar, wind, hydro), even though such diversity could enhance self-sufficiency and grid stability.
- Ensuring the economic viability of the community requires time and resources, which may increase energy costs and affect affordability for members.
- Participatory processes that involve all members in decision-making strengthen the community but can be time- and resource-intensive, potentially conflicting with economic efficiency and affordable energy prices.
- Transparency is vital for trust within the community but must be balanced with data privacy concerns. This balance should be openly discussed and clearly documented.
- Investing in local products and services boosts regional value creation but can be more costly than global alternatives, which might impact economic sustainability.
- Expanding renewable energy is crucial for the energy transition but must be carefully balanced with environmental protection to ensure long-term ecological sustainability.

Table 1: Summary of implementation results by category, calculated from responses to the questions in Table 4.

		Number of questions answered with "applies"	Total number of questions per category.	Number of "Not relevant" and "No information available"	Result (R):
No.	**Category**	**(A)**	**(B)**	**(C)**	$\mathrm{E} = \frac{A}{B - C}$
1	Ecology & Health		9		
2	Self-Sufficiency & Supply Security		7*		
3	Affordable Energy & Economic Viability		5		
4	Regional Development		7		
5	Education & Research		6		
6	Equal Opportunities Inclusive Processes		18		
7	Community Benefit		3		

** 7 if indicator question 2.4 is included, 6 if it is excluded.*

Ecology and Health	Energy Consumption	Proportion of Renewable Energy	Eco-Design of Equipment	Environmental Protection and Biodiversity	Protection of the Visual Landscape
Self-Sufficiency and Supply Security	Self Sufficiency Rate	Contribution to Grid Stability	Security of Supply	Local / Regional Energy Generation	
Affordable Energy & Economic Viability	Energy Prices	Economic Viability			
Regional Development	Regional Value Creation	Public-benefit Investments	Regional Cooperation	Community Activities	
Education & Research	Awareness-Raising	Educational Opportunities	Research and Knowledge Exchange		
Equal Opportunity & Inclusive Processes	Inclusion and Participation	Transparent Processes	User-Friendly Procedures		
Community Benefit	Member Satisfaction & Quality of Life				

Figure C1: Overview of categories and corresponding criteria used in the evaluation.

Importance of the categories for the energy community (Self-assessment)

Please rate the significance of each category for your energy community.

5 → Very high importance

1 → Very low importance

Table 2: Self-assessed importance of each category – used to compare perceived relevance with actual implementation.

Category	1	2	3	4	5	Number / 5
Ecology & Health						
Self-Sufficiency & Supply Security						
Affordable Energy & Economic Viability						
Regional Development						
Education & Research						
Equal Opportunity & Inclusive Processes						
Community Benefit						

Additional Questions for the Self Assessment

1) What do you consider to be the unique strengths of your energy community regarding sustainable development?

____
____
____
____

2) Has this evaluation inspired any new ideas for your energy community?

____
____
____
____

3) What support do you need to implement your ideas or goals (e.g., policy conditions, communication tools, expert knowledge, etc.)?

____
____
____
____
____

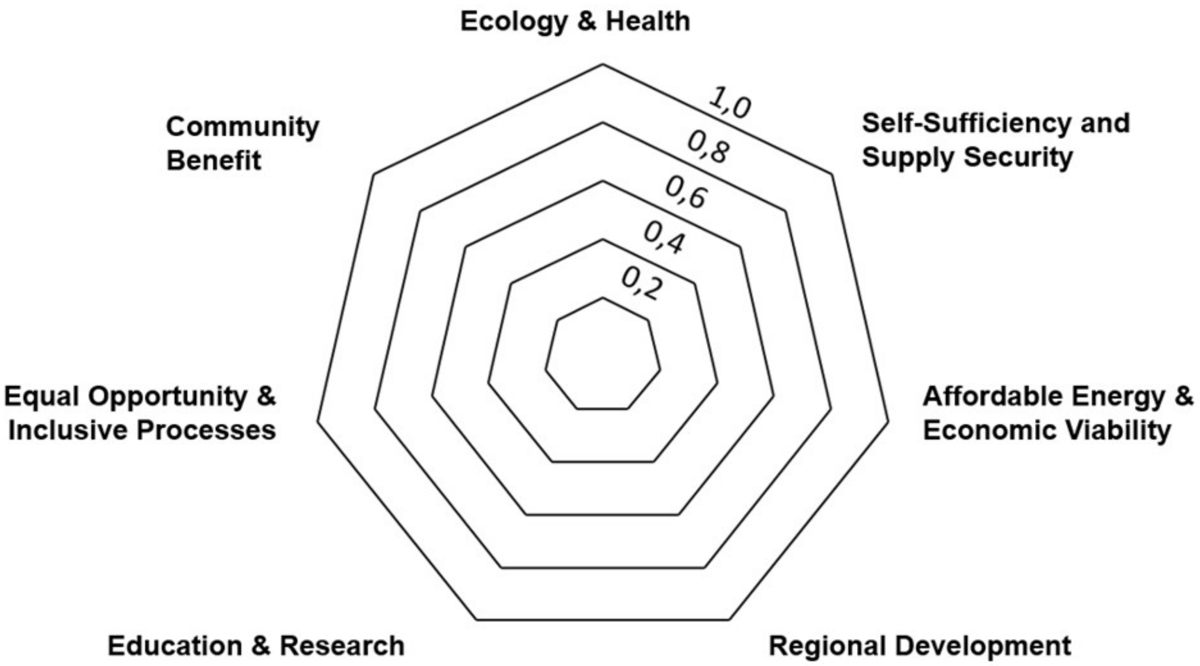

Figure C2: Radar chart for visualizing results. Implementation data (from Table 1) is plotted alongside self-assessed importance (from Table 2) to highlight differences between actual practice and perceived relevance.

Reflections and Next Steps (after completing Tables 1 and 2)

Goal Setting: Based on the evaluation, we want to set the following goals:

Next Steps: We intend to implement these measures to achieve the goals of the energy community:

Table 3: General information on the energy community – metadata to support sorting and contextual analysis of results.

General Questions	
Name of the energy community:	
Location:	
Type of energy community:	◻ Renewable energy community (REC) ◻ Citizen Energy Community (CEC)
Proximity criterion:	◻ Local (REC) ◻ Regional (REC) ◻ Cross-regional (CEC)
Role:	◻ Board / Manager ◻ Participation including energy generation ◻ Participation / Usage
Approximate number of members:	

Table 4: Full list of evaluation questions – forms the basis for calculating fulfilment levels in Table 1. Questions are labeled according to whether they are directed at board members (organizational or administrative roles), participants (non-administrative members), or both. Questions that concern only the board / managers are highlighted in gray.

		Applies	Does not apply	Not relevant	No information available
Category 1: Ecology and Health					
Criterion 1.1.: Energy consumption					
Board / Participant:					
1.1.a	Since joining the energy community, have you become more conscious of your energy consumption (e.g. using household appliances more deliberately or heating more carefully) with the goal of reducing your energy use?				
1.1.b	Since joining the energy community, have you been using devices such as electric vehicles or heat pumps that promote the use of energy from the community?				
Criterion 1.2.: Proportion of Renewable Energy					
Board:					
1.2.a	Has the proportion of renewable energy generation relative to the total energy generation increased since the energy community was founded? (Criterion relevant for CECs)				
1.2.b	Is there an ongoing discussion within the energy community about expanding or increasing renewable energy generation?				
Criterion 1.3.: Eco-design of Equipment (Generation and Consumption Devices)					
Board / Participant:					
1.3.a	Are the following aspects considered or discussed when purchasing generation systems or consumption devices: eco-labels, recyclability, lifespan, critical raw materials, etc.?				
Criterion 1.4.: Environmental Protection and Preservation of Biodiversity					
Board / Participant:					
1.4.a	Since the energy community was founded, are generation systems preferentially installed on built-up or previously used areas (e.g. roofs, agri-PV) in order to avoid converting green spaces?				
Board:					
1.4.b	Are measures implemented to protect the ecosystem (e.g. bird protection markings or intelligent turbine shutdowns for wind turbines, use of biowaste for energy production)?				
1.4.c	Is any surplus revenue from the energy community invested in green ecological landscaping elements (e.g. natural meadows or lawns, green walls)?				
Criterion 1.5.: Preservation of the Landscape					
1.5.a	Is special importance placed on protecting landscape areas with distinctive features and natural beauty?				

Category 2: Self-Sufficiency and Supply Security					
Criterion 2.1.: Self-Sufficiency Rate					
Board:		**Applies**	**Does not apply**	**Not relevant**	**No information available**
2.1.a	Has the energy community set a goal for its self-sufficiency rate? Note: Self-sufficiency rate = electricity generated and consumed within the energy community / total electricity consumption of the energy community (%)				
2.1.b	Are members of the energy community satisfied with their self-sufficiency rate?				
Criterion 2.2.: Contribution to Grid Stability					
Board:					
2.2.a	Does the energy community use two or more energy sources for power generation (e.g. solar, wind, hydropower, biomass, geothermal)?				
Board / Participant:					
2.2.b	Have measures been implemented for the intelligent use of energy (e.g. installation of energy storage systems, energy management systems, grid-friendly charging of electric vehicles, automatic control of heat pumps, grid-friendly charging of energy storage)?				
Board:					
2.2.c	If yes: Have the peak loads of the energy community been reduced since the implementation of the intelligent measures?				
Criterion 2.3.: Security of Supply					
Board:					
2.3.a	Is there an emergency power system in place for the energy community in case of a blackout, or have other precautions been taken?				
Criterion 2.4.: Local and Regional Energy Generation					
Board:					
2.4.a	Is your energy community a local or regional energy community?				
Category 3: Affordable Energy and Economic Viability					
Criterion 3.1.: Energy Prices					
Board/ Participant:					
3.1.a	Are the tariffs within the energy community lower compared to standard market supply tariffs?				
3.1.b	Is special consideration given to households struggling to afford their electricity costs (e.g. special tariffs for energy-poor households, donations of electricity)?				
Criterion 3.2.: Economic Viability					
Board:					
3.2.a	Is there a business plan for the energy community?				
3.2.b	Are regular reviews and adjustments of tariffs or fees in place to ensure the economic stability of the energy community?				
3.2.c	Are financing support options such as grants, loans, or participation models availed of for the expansion of renewable energies, for services or consulting?				

Category 4: Regional Development					
Criterion 4.1.: Regional Value Creation					
Board / Participant:		**Applies**	**Does not apply**	**Not relevant**	**No information available**
4.1.a	Are regional businesses (e.g. installers) preferred?				
4.1.b	Is there an emphasis on using Austrian or European products or equipment?				
Board:					
4.1.c	Have new companies been founded as a result of the energy community?				
Criterion 4.2.: Public-Benefit Investments					
Board:					
4.2.a	Is any surplus money generated by the energy community invested in social infrastructure or community-beneficial projects? (e.g. educational or healthcare facilities, building insulation, electric vehicle charging stations, generation plants, or energy storage systems)				
Criterion 4.3.: Regional Cooperation					
Board / Participant:					
4.3.a	Does your energy community exchange experiences with other energy communities?				
Board:					
4.3.b	Does your energy community exchange experiences with other institutions (e.g. municipalities, public organizations, small and medium-sized enterprises, private individuals)?				
Criterion 4.4.: Community Activities					
Board / Participant:					
4.4.a	Has the energy community initiated additional community activities (e.g. mobility sharing concepts, etc.)?				
Category 5: Education and Research					
Criterion 5.1.: Awareness-Raising					
Board / Participant:					
5.1.a	Is there an opportunity within the energy community to share information or discuss energy or sustainability topics (e.g. via email distribution lists, group chats, member meetings)?				
5.1.b	Has your understanding of energy or sustainability topics increased since joining the energy community?				
Criterion 5.2.: Educational Opportunities					
Board:					
5.2.a	Are training and education opportunities being utilized that benefit the energy community (e.g. in energy technology, consulting, law, management, environment)?				
Board / Participant:					
5.2.b	Are training opportunities offered and used within the energy community (e.g. guest lectures, involvement of experts in meetings)?				
Criterion 5.3.: Research and Knowledge Exchange					
Board:					
5.3.a	Is the energy community involved in research activities?				
5.3.b	Are scientific networking opportunities being utilized?				

Category 6: Equal Opportunity and Inclusive Processes					
Criterion 6.1.: Inclusion and Participation					
Board / Participant:		**Applies**	**Does not apply**	**Not relevant**	**No information available**
6.1.a	Are decisions (e.g. pricing and price adjustments) made inclusively, through discourse, and democratically? If not, is the management team representative and diverse?				
6.1.b	Are all stakeholder groups involved early in new processes? (e.g., participants, grid operators, housing developers)				
6.1.c	Are forms, documents, information, and process descriptions formulated in a gender and diversity-sensitive manner?				
6.1.d	Is diversity actively considered during member recruitment? (e.g., gender, origin, age)				
Criterion 6.2.: Transparent Processes					
Board / Participant:					
6.2.a	Are the goals within the energy community clearly defined and visible?				
6.2.b	Are responsibilities clearly defined and visible?				
6.2.c	Are processes clearly defined and transparent?				
6.2.d	Is the pricing and cost structure clearly and unambiguously communicated?				
6.2.e	Are regular updates and information about energy consumption, production, and distribution available?				
6.2.f	Are economic risks clearly communicated?				
6.2.g	Are data security and cybersecurity measures implemented?				
6.2.h	Is data security explained and openly discussed?				
Criterion 6.3.: User-Friendly Procedures					
Board / Participant:					
6.3.a	Are the participation procedures and processes written in clear, easy-to-understand language, organized clearly, and made accessible?				
6.3.b	Are general meetings held at times when all members can participate?				
6.3.c	Is the location of the meetings centrally accessible and barrier-free?				
6.3.d	Are different communication channels used (e.g. online platforms, discussion rounds, general meetings, group chats, postal mail)?				
6.3.e	Is there a contact person or trusted individual available for people with disabilities or those who have difficulty with technical processes?				
6.3.f	Are the responsible persons for different areas and issues known and available via telephone (e.g. for technical problems, conflict management)?				
Category 7: Community Benefit					
Criterion 7.1.: Member Satisfaction and Quality of Life					
Board / Participant:					
7.1.a	Are you satisfied with your membership in the energy community?				
7.1.b	Do you believe that your quality of life has improved through your participation in the energy community?				
7.1.c	Does participating in the energy community give you a sense of being involved in the energy transition?				

9.3 Appendix C: Supplemental Information Simulations

This appendix provides supporting information and methodological context for the findings presented in Section 5.2.3. While Section 5.2.3 summarized the key results of a simulated storage deployment in an energy community setting, the following sections detail the underlying assumptions, data sources, and modelling approach used to derive those results. Additional examples and disaggregated outcomes are included to illustrate how specific conclusions—such as the benefits of community-oriented storage operation—were reached. This supplementary analysis also includes further scenario comparisons and household-level insights that reinforce the observed trends and help clarify the potential and limitations of storage-based optimization in real-world energy communities. Illustrations courtesy of 4ward Energy Research GmbH (4ward).

9.3.1 Simulation Methods: Battery Storage

In contrast to the forecast-based simulations used in Section 5.2.3 to compare different forecasting approaches, this analysis focused on assessing the potential contribution of residential storage systems to increasing self-consumption within energy communities. It is based on historical data and therefore assumes a perfect forecast of both generation and consumption, allowing for a clearer comparison of storage operation strategies under idealized conditions.

Two energy communities provided by project partner neoom were selected to reflect differing structural and consumption characteristics. Within each community, two to three households equipped with photovoltaic (PV) systems—but without battery storage—were selected for the simulation. Using actual historical load and generation data, each household's energy profile was modelled, and the impact of adding a 20-kWh battery storage system was analyzed through scenario-based simulation.

Three operational scenarios were modelled to explore alternative approaches to storage use. A representative tariff structure was applied to evaluate economic impacts and assess potential cost savings under each scenario. Table VIII-Table X provide an overview of the tested scenarios, the tariff model used, and the characteristics of the participating prosumers.

Table VIII: Simulated Storage Operation Scenarios - Overview of Simulated Storage Operation Scenarios. Description of the three scenarios used to evaluate the impact of residential storage systems on energy distribution and economic outcomes within energy communities (4ward).

Scenario SN0	Base	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.
Scenario SN1	Self-sufficiency optimization	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.
Scenario SN2	Self-sufficiency + community optimization	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.

Table IX: Tariff Structure Used in Simulation - Tariff Structure Applied in Simulation. Electricity pricing used in the analysis. Consumption Grid and Consumption EC refer to the costs paid by end users for electricity from the public grid and the energy community, respectively, including both energy and grid charges. Feed-in EC and Feed-in Grid indicate payments received by prosumers for energy sold to the community or external supplier, based on the energy component only (4ward).

Consumption Grid (Energy + Grid)	29.60 ct/kWh
Consumption EC (Energy + Grid)	18.2 ct/kWh
Feed in Tariff EC	10 ct/kWh
Feed in Tariff Grid	6 ct/kWh

Table X: Characteristics of Simulated Prosumers - Characteristics of Simulated Prosumers. Overview of the households included in the simulation, including photovoltaic (PV) peak capacity and relevant property features that influence electricity demand, such as electric vehicles, heat pumps, and household size (4ward).

Ref.	PV-Peak Power	Properties
Prosumer A	7.77 kWp	Electric car and Heat pump
Prosumer B	27 kWp	n/a
Prosumer C	10 kWp	4 People, Heat pump
Prosumer D	10 kWp	Electric car and Heat pump, 4 Persons
Prosumer E	12.9 kWp	Heat pump, Wellness (Sauna/Pool)

9.3.2 Results: Simulated Storage

The results show a consistent pattern across all analyzed prosumers. When storage is operated solely for self-sufficiency (Scenario SN1), the amount of energy fed into the community decreases by 40% to 79% compared to the baseline without storage (Scenario SN0). This reflects the fact that surplus energy is retained for individual use rather than shared within the energy community. In contrast, under the combined self-sufficiency and community-optimized strategy (Scenario SN2), the volume of energy delivered to the community increases substantially—by 149% to over 1000%, also relative to the baseline—as storage is used not only to meet household demand but also to supply other community members when local demand exists and compensation is more favorable. This shift supports greater local utilization of renewable energy and reduces reliance on external energy suppliers.

Figure 31 compares two battery storage operation strategies across five prosumers, highlighting their impact on electricity flows and grid interaction. Grid Consumption refers to the reduction in electricity drawn from the public grid. Infeed COOP (rel) and Infeed COOP (abs) represent the percentage and absolute changes, respectively, in energy delivered by the prosumer to the energy community. The term COOP refers to the optimization platform used to manage intra-community energy exchange and is used here as shorthand for energy community interactions. Infeed EVU indicates the change in electricity exported to the external energy supplier. All values are shown relative to Scenario SN0 (baseline without storage).

It should be noted that extremely high percentage increases (such as the 1000%+ range) can occur when baseline values are very low. In such cases, even moderate absolute changes can yield large relative differences. These figures should therefore be interpreted in the context of the actual energy volumes involved.

		Gird Consumption	Infeed Coop (rel)	Infeed Coop (abs)	Infeed EVU
Self sufficiency optimisation	Prosumer A	-42%	-79%	-385,6 kWh	-44%
	Prosumer B	-91%	-40%	-918,3 kWh	-6%
	Prosumer C	-71%	-64%	-329,3 kWh	-35%
	Prosumer D	-73%	-61%	-127,7 kWh	-31%
	Prosumer E	-80%	-58%	-177,5 kWh	-22%
		Gird Consumption	Infeed Coop (rel)	Infeed Coop (abs)	Infeed EVU
Self sufficiency optimisation **+ EEG optimisation**	Prosumer A	-38%	293%	1816,6 kWh	-78%
	Prosumer B	-84%	149%	4362,3 kWh	-28%
	Prosumer C	-65%	344%	2088 kWh	-63%
	Prosumer D	-65%	1051%	2314 kWh	-31%
	Prosumer E	-72%	787%	2599,4 kWh	-61%

Figure 31: Survey: Community Benefit - Comparison of storage strategies showing changes in grid consumption (decreasing), energy delivered to the energy community (Infeed COOP, increasing), and energy exported to the external supplier (Infeed EVU, decreasing). COOP refers to the community optimization platform used to manage intra-community energy exchange. All values are shown relative to Scenario SN0 (baseline without storage).(4ward).

These operational differences also result in measurable economic impacts. Under the self-sufficiency strategy, annual cost savings for individual prosumers range from approximately €360 to €610. By enabling additional energy sales within the community in Scenario SN2, further annual savings of €28 to €139 are achieved, depending on each household's consumption and generation profile. These additional benefits result from the higher feed-in tariff available for energy delivered to the community compared to the public grid.

It should also be noted that these figures reflect savings based on energy tariffs alone. The costs associated with the purchase, installation, and operation of the battery storage systems were not included in this analysis. As such, a portion of the reported savings would need to be allocated toward financing the storage investment in a full economic assessment.

Figure 32 presents the cost savings achieved by individual prosumers under the two storage operation strategies. The first column, Self-sufficiency opt, shows the reduction in electricity costs when battery storage is operated to maximize local self-consumption. The column Additional Full Opt represents the further annual savings generated through the community-optimized strategy, which allows stored energy to be supplied to the energy community when local demand exists and tariffs are more favorable. These additional earnings reflect the improved compensation available within the community compared to feed-in to the public grid.

		Self sufficiency opt	Additional Full Opt
Cost reduction	Prosumer A	-€ 559,21	-€ 28,09
	Prosumer B	-€ 468,52	-€ 138,99
	Prosumer C	-€ 607,01	-€ 32,43
	Prosumer D	-€ 474,35	-€ 37,50
	Prosumer E	-€ 364,72	-€ 68,46

Figure 32: Annual Cost Reductions - Annual cost reductions per prosumer under (1) self-sufficiency optimization and (2) full community-aware optimization. "Additional Full Opt" reflects the extra savings gained by supplying energy to the energy community at higher feed-in tariffs (4ward).

The additional value of community-oriented storage optimization can be illustrated more concretely by looking at the results for an individual prosumer—in this case, Prosumer C. Figure 33 compares the three scenarios and highlights how energy flows shift under each strategy. In Scenario SN2, the volume of energy delivered to the energy community increases by approximately 1,500 kWh. At the same time, grid consumption is reduced by 2,500 kWh, and feed-in to the external supplier (EVU) is reduced by 4,000 kWh. This outcome demonstrates the combined effect of optimized battery operation and forecast-based scheduling in increasing local energy use and improving economic returns.

Prosumer C represents one of the more favorable cases in the analysis. This may be due to a household load profile that includes energy consumption during early morning or evening hours, which can be covered by stored solar energy. In addition, surplus PV generation during the day can be sold into the energy community when local demand exists and pricing conditions are more advantageous. These factors reinforce the value of predictive, community-oriented storage strategies—though results will vary depending on each household's specific generation and consumption patterns.

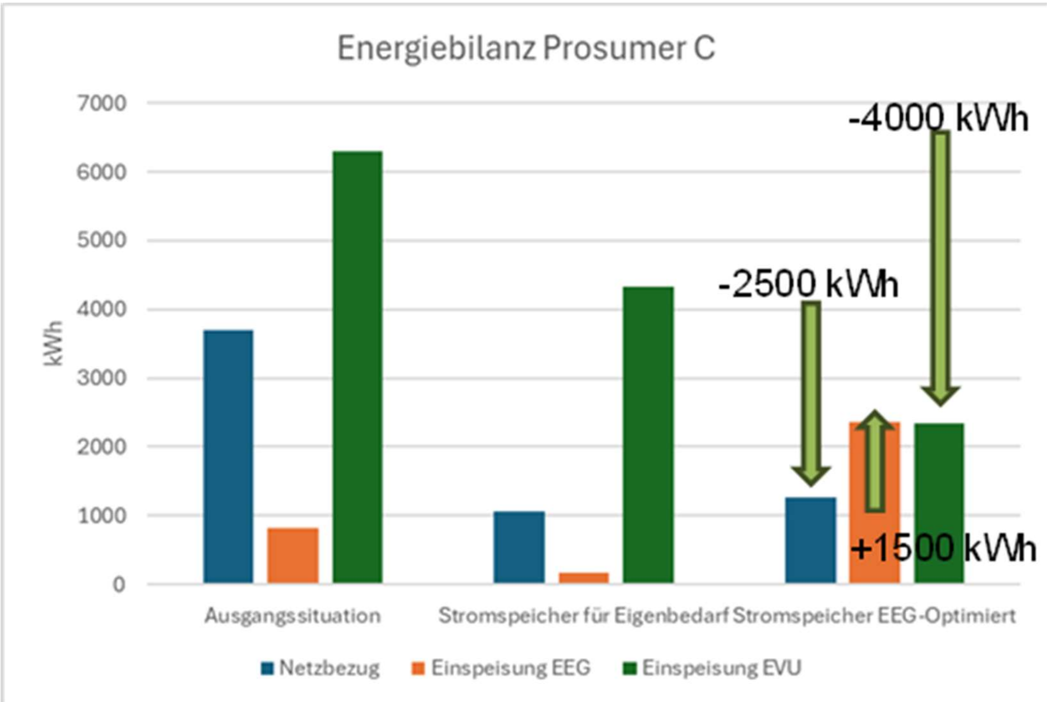

Figure 33: Scenario Comparison: Prosumer C - Energy distribution comparison across scenarios for Prosumer C. Ausgangssituation (EN: SN0 Baseline scenario), Stromspeicher für Eigenbedarf (EN: SN1 Storage for self-consumption), and Stromspeicher EEG-Optimiert (EN: SN2 Storage with community optimization). The bars represent Netzbezug (EN: Grid consumption), Einspeisung EEG (EN: Feed-in to energy community), and Einspeisung EVU (EN: Feed-in to external supplier).(4ward).

9.4 Appendix D: Data Validation and Preprocessing

As outlined in Section 6.2: *Monitoring and Analysis Methods*, a key part of the project's evaluation approach involved analyzing real-world energy data from the testbeds to assess the performance of different energy community configurations. Reliable input data was essential for calculating energy indicators, simulating alternative scenarios, and estimating potential benefits such as self-sufficiency and cost savings. This appendix provides a detailed overview of the data preparation process used to clean, validate, and complete the measurement data before analysis.

The measurement data provided by project partners—including outputs from photovoltaic (PV) systems, battery storage, and the power grid—were analyzed and prepared to establish a reliable foundation for evaluating energy flows and community configurations. The objective was to identify anomalies, address missing values, and ensure that the data were both complete and physically plausible.

In addition to cleaning and validating the data, various energy indicators were calculated, including self-sufficiency and self-consumption ratios. These metrics informed the modeling of different energy community scenarios, using both static and dynamic allocation methods. A profitability analysis was also conducted to estimate potential economic benefits and identify areas for optimization.

The data preparation process involved four main steps:

Step 1: Structuring and Initial Validation

Measurement data were extracted from provided CSV files and standardized into a consistent format. Initial plausibility checks were performed, including a review of the five highest PV production values per site. These peak values were later cross-checked to confirm consistency with system size, helping to detect and correct any unrealistic values.

Step 2: Addressing Missing Battery Storage Data

Missing battery values were completed using simplified assumptions. In cases of brief data outages, the battery was assumed to act as a passive energy conduit—passing energy from the PV system to the building or grid without charging or discharging. This approach avoided the introduction of additional errors from simulated battery state-of-charge (SOC) tracking.

Step 3: Filling PV Gaps and Removing Outliers

PV production gaps were filled by referencing a comparable system in the same municipality with similar orientation. The reference data were scaled according to system size to reconstruct missing values.

Outlier filtering included:

- Removing values exceeding 110% of the installed PV system's capacity.
- Deleting small PV readings during nighttime hours (10 PM to 3 AM).
- Ensuring that calculated energy consumption values were never negative—any such cases were corrected by adjusting PV production to restore energy balance.

These adjustments addressed common errors such as inverted meter readings or incomplete substitutions from reference data.

Step 4: Completing Grid Power Data and Calculating Consumption

To complete the dataset, remaining gaps in grid power values were estimated using neighboring time points. Where historical consumption values existed one or two weeks before or after the missing timestamp, they were used to interpolate or average expected consumption. Grid power was then back-calculated using the energy balance equation (consumption = PV + battery + grid). This method ensured that all energy flows could be reconstructed as accurately and consistently as possible.

The resulting dataset enabled reliable analysis of energy flows between PV systems, batteries, and the grid. The combination of plausibility checks, rule-based substitution, and historical interpolation allowed for a fully automated and repeatable data preparation process.

10 Sources

Anda, M., Temmen, J., 2014. Smart metering for residential energy efficiency: The use of community based social marketing for behavioural change and smart grid introduction. Renewable Energy, Renewable Energy for Sustainable Development and Decarbonisation 67, 119–127. https://doi.org/10.1016/j.renene.2013.11.020.

Bauwens, T., Devine-Wright, P., 2018. Positive energies? An empirical study of community energy participation and attitudes to renewable energy. Energy Policy 118, 612–625. https://doi.org/10.1016/j.enpol.2018.03.062.

BMEIA, 2024. Österreich und die Agenda 2030. 2. Freiwilliger Nationaler Bericht zur Umsetzung der Agenda 2030 und der Nachhaltigen Entwicklungsziele / SDGs in und durch Österreich, (FNU). Bundeskanzleramt, Ballhausplatz 2, 1010 Wien, Wien.

BMK, 2022. Die österreichische Kreislaufwirtschaftsstrategie. Österreich auf dem Weg zu einer nachhaltigen und zirkulären Gesellschaft. https://www.bmimi.gv.at/dam/jcr:9377ecf9-7de5-49cb-a5cf-7dc3d9849e90/Kreislaufwirtschaftsstrategie_2022_230215.pdf (accessed 2.22.25).

BMK, 2020. Mit Energiegemeinschaften werden Bürgerinnen und Bürger Teil der Energiewende. BMK Redaktion. https://infothek.bmimi.gv.at/energiegemeinschaften-energiewende-erneuerbare-act4energy/ (accessed 2.22.25).

Bomberg, E., McEwen, N., 2012. Mobilizing community energy. Energy Policy 51, 435–444. https://doi.org/10.1016/j.enpol.2012.08.045.

Boon, F. P., Dieperink, C., 2014. Local civil society based renewable energy organisations in the Netherlands: Exploring the factors that stimulate their emergence and development. Energy Policy 69, 297–307. https://doi.org/10.1016/j.enpol.2014.01.046.

Brundtland Report, 1987. Report of the World Commission on Environment and Development: Our Common Future.

Calliess, C., 2013. Vorsorgeprinzip, in: Grunwald, A., Simonidis-Puschmann, M., (Eds.), Handbuch Technikethik. J.B. Metzler, Stuttgart, 390–394. https://doi.org/10.1007/978-3-476-05333-6_74.

Campos, I., Marín-González, E., 2020. People in transitions: Energy citizenship, prosumerism and social movements in Europe. Energy Research & Social Science 69, 101718. https://doi.org/10.1016/j.erss.2020.101718.

Chowdhury, P., Chowdhury, N.-U.-R., Farrok, O., 2025. Complementarity in renewable energy sources: Insights from scientometric analysis. Energy Conversion and Management: X 26, 100930. https://doi.org/10.1016/j.ecmx.2025.100930.

Clean Energy Package, 2019. https://www.acer.europa.eu/electricity/about-electricity/clean-energy-package (accessed 2.22.25).

Codemo, A., Ghislanzoni, M., Prados, M.-J., Albatici, R., 2024. Incorporating public perception of Renewable Energy Landscapes in local spatial planning tools: A case study in Mediterranean countries. Applied Geography 170, 103358. https://doi.org/10.1016/j.apgeog.2024.103358.

Conradie, P. D., Ruyck, O. de, Saldien, J. & Ponnet, K., 2021. Who wants to join a renewable energy community in Flanders? Applying an extended model of Theory of Planned Behaviour to understand intent to participate. Energy Policy 151, 112121 https://doi.org/10.1016/j.enpol.2020.112121.

Digitales Institut, 2023. Die Vorteile der Autarkie: Unabhängigkeit und Nachhaltigkeit - Digitales Institut. https://digitales-institut.de/die-vorteile-der-autarkie-unabhaengigkeit-und-nachhaltigkeit/ (accessed 4.7.25).

Dóci, G., Vasileiadou, E., Petersen, A. C., 2015. Exploring the transition potential of renewable energy communities. Futures 66, 85–95. https://doi.org/10.1016/j.futures.2015.01.002.

Dworatzek, L., Santucci, D., van Treeck, C., 2025. Assessing the impact of local energy generation and storage to achieve the decarbonization of the single-family housing stock in Germany. Energy and Buildings 327, 115068. https://doi.org/10.1016/j.enbuild.2024.115068.

ESPR, 2024. Ecodesign for Sustainable Products Regulation - European Commission. https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/ecodesign-sustainable-products-regulation_en (accessed 1.18.25).

European Commission, 2025a. Energy communities. https://energy.ec.europa.eu/topics/markets-and-consumers/energy-consumers-and-prosumers/energy-communities_en (accessed 4.3.25).

European Commission, 2025b. Energy efficiency targets. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-targets_en (accessed 4.7.25).

European Commission, 2025c. Renewable energy targets - European Commission. https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets_en (accessed 4.7.25).

eurostat, 2024. Statistiken über erneuerbare Energien. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics (accessed 4.7.25).

Felice, A., Rakocevic, L., Peeters, L., Messagie, M., Coosemans, T., Ramirez Camargo, L., 2022. Renewable energy communities: Do they have a business case in Flanders? Applied Energy 322, 119419. https://doi.org/10.1016/j.apenergy.2022.119419.

Frieden, D., Gubina, A., d´Herbemont, S., Tuerk, A., Roberts, J., 2019. Collective self-consumption and energy communities. https://www.compile-project.eu/wp-content/uploads/COMPILE_Collective_self-consumption_EU_review_june_2019_FINAL-1.pdf (accessed 7.2.2022).

Gährs, S., Bluhm, H., Kütemeyer, L., 2022. Nachhaltige Digitalisierung einer dezentralen Energiewende (Projektbericht SteuerBoard Energie).

Grunwald, A., Kopfmüller, J., 2022. NACHHALTIGKEIT, 3. Auflage. ed. Campus, Frankfurt am Main.

Günther, E., Schuh, H., 2000. Definitionen, Konzepte, Kriterien und Indikatoren einer nachhaltigen Entwicklung. Dresdner Beiträge zur Betriebswirtschaftslehre. Die Professoren der Fachgruppe Betriebswirtschaftslehre, Dresden.

He, J., Feng, T., Wei, R., 2025. A dynamic framework for optimizing peer-to-peer energy sharing: Enhancing local consumption and reducing power losses in smart grids. Electric Power Systems Research 239, 111215. https://doi.org/10.1016/j.epsr.2024.111215.

Hicks, J., Ison, N., 2018. An exploration of the boundaries of 'community' in community renewable energy projects: Navigating between motivations and context. Energy Policy, 113, 523–534. https://doi.org/10.1016/j.enpol.2017.10.031.

Hoicka, C. E., Lowitzsch, J., Brisbois, M. C., Kumar, A., Ramirez Camargo, L., 2021. Implementing a just renewable energy transition: Policy advice for transposing the new European rules for renewable energy communities. Energy Policy 156, 112435. https://doi.org/10.1016/j.enpol.2021.112435.

Jahn, T., 2021. Transdisziplinäre Nachhaltigkeitsforschung – Methoden, Kriterien, gesellschaftliche Relevanz, in: Blättel-Mink, B., Hickler, T., Küster, S., Becker, H. (Eds.), Nachhaltige Entwicklung in einer Gesellschaft des Umbruchs. Springer Fachmedien, Wiesbaden, 141–157. https://doi.org/10.1007/978-3-658-31466-8_8.

Kaiser, S., Oliveira, M., Vassillo, C., Orlandini, G., Zucaro, A., 2022. Social and Environmental Assessment of a Solidarity Oriented Energy Community: A Case-Study in San Giovanni a Teduccio, Napoli (IT). Energies 15, 1557. https://doi.org/10.3390/en15041557.

Kalkbrenner, B. J. & Roosen, J., 2016. Citizens' willingness to participate in local renewable energy projects: The role of community and trust in Germany. Energy Research & Social Science 13, 60–70. https://doi.org/10.1016/j.erss.2015.12.006.

Katrin Martens, 2022. Investigating subnational success conditions to foster renewable energy community co-operatives - 1-s2.0-S0301421522000210-main. Energy Policy.

Koordinationsstelle, 2024. Best Practice – Energiegemeinschaften. https://energiegemeinschaften.gv.at/bestpractice/ (accessed 4.10.25).

Koordinationsstelle, 2023. Tarifgestaltung – Energiegemeinschaften. https://energiegemeinschaften.gv.at/tarifgestaltung/ (accessed 4.10.25).

Koordinationsstelle, 2022. Erneuerbare-Energie-Gemeinschaften Rechtsformen.

Košnjek, E., Sučić, B., Kostić, D., Smolej, T., 2024. An energy community as a platform for local sector coupling: From complex modelling to simulation and implementation. Energy 286, 129478. https://doi.org/10.1016/j.energy.2023.129478.

Kowalska-Pyzalska, A., 2018. What makes consumers adopt to innovative energy services in the energy market? A review of incentives and barriers. Renewable and Sustainable Energy Reviews 82, No. P3, 3570–3581.

Kropp, A., 2019. Die Dimensionen der Nachhaltigkeit, in: Kropp, A. (Ed.), Grundlagen der Nachhaltigen Entwicklung: Handlungsmöglichkeiten und Strategien zur Umsetzung. Springer Fachmedien, Wiesbaden, 11–12. https://doi.org/10.1007/978-3-658-23072-2_4.

Llewellyn, J., Katzeff, C., Pargman, D., Johansson, F., 2024. Citizen perceptions and interactions towards self-sufficiency, community plot ratio and civic generosity within sustainable neighbourhoods. City and Environment Interactions 24, 100180. https://doi.org/10.1016/j.cacint.2024.100180.

Lyhs, W., 2022. Kritische Rohstoffe. Global Energy Solutions e.V. https://global-energy-solutions.org/wp-content/uploads/2022/10/kritische_rohstoffe_kurzversion_wilfried_lyhs-1.pdf (accessed 4.25.25).

Ma, B., Wang, A., 2025. Exploring the role of renewable energy in green job creation and sustainable economic development: An empirical approach. Energy Strategy Reviews 58, 101642. https://doi.org/10.1016/j.esr.2025.101642.

McKenna, R., Herbes, C., Fichtner, W., 2015. Energieautarkie: Definitionen, Für- bzw. Gegenargumente, und entstehende Forschungsbedarfe. Karlsruhe. https://doi.org/10.5445/IR/1000047347.

Mura, E., Schito, E., Conti, P., Testi, D., Raugi, M., 2025. Behavioral flexibility in demand response: A comparison of energy communities and individual prosumers based on real consumption and flexibility data. Energy and Buildings 331, 115346. https://doi.org/10.1016/j.enbuild.2025.115346.

Mutani, G., Santantonio, S., Brunetta, G., Caldarice, O., Demichela, M., 2021. An energy community for territorial resilience: Measurement of the risk of an energy supply blackout. Energy and Buildings 240, 110906. https://doi.org/10.1016/j.enbuild.2021.110906.

Obier, M., 2023. Einsatz und Bewertung von Digitalisierungsmaßnahmen für Teilnehmer*innen in Energiegemeinschaften, Master's Thesis, FH Technikum Wien.

Palm, J., Kojonsaari, A.-R., Magnusson, D., 2025. Toward energy democracy: Municipal energy actions in local renewable energy projects. Energy Research & Social Science 120, 103921. https://doi.org/10.1016/j.erss.2025.103921.

Panda, S., Mohanty, S., Rout, P.K., Sahu, B.K., Parida, S.M., Samanta, I.S., Bajaj, M., Piecha, M., Blazek, V., Prokop, L., 2023. A comprehensive review on demand side management and market design for renewable energy support and integration. Energy Reports 10, 2228–2250. https://doi.org/10.1016/j.egyr.2023.09.049.

Pasqui, M., Gerini, F., Jacobs, M., Carcasci, C., Paolone, M., 2025. Self-dispatching a renewable energy community by means of battery energy storage systems. Journal of Energy Storage 114, 115837. https://doi.org/10.1016/j.est.2025.115837.

Preßmair, G., Mayr, M., Benke, G., 2024. Welchen Beitrag liefern Energiegemeinschaften zur Energiewende? Eine Kritische Diskussion (18. Symposium Energieinnovation, 14.-16.02.2024, Graz/Austria).

Purvis, B., Mao, Y., Robinson, D., 2019. Three pillars of sustainability: in search of conceptual origins. Sustainability Science 14, 681–695. https://doi.org/10.1007/s11625-018-0627-5.

Rahadian, D., Anggadwita, G., Firli, A., Adibroto, A., 2025. Chapter 6 - Environmental impact of renewable energy projects: life cycle assessment and ecological footprint, in: Dinçer, H., Yüksel, S. (Eds.), Renewable Energy Projects and Investments. Elsevier, 95–116. https://doi.org/10.1016/B978-0-443-29869-1.00006-4.

Reindl, K., Dalhammar, C., 2024. Circular Economy Integration in Smart Grids. IIIEE, Lund University. https://doi.org/10.1007/s43615-024-00375-5.

Rogall, H., 2002. Operationalisierung des Begriffs Nachhaltigkeit, in: Rogall, H. (Ed.), Neue Umweltökonomie — Ökologische Ökonomie: Ökonomische und ethische Grundlagen der Nachhaltigkeit, Instrumente zu ihrer Durchsetzung. VS Verlag für Sozialwissenschaften, Wiesbaden, 171–211. https://doi.org/10.1007/978-3-322-99733-3_7.

Schall, D. L., 2020. More than money? An empirical investigation of socio-psychological drivers of financial citizen participation in the German energy transition. Cogent Economics & Finance 8, Nr. 1, 1777813. https://doi.org/10.1080/23322039.2020.1777813 (accessed 5.4.22).

Schnifis, 2022. Erneuerbare Energie Gemeinschaft verbindet die Stromproduktion mit regenerativer Landwirtschaft. https://innovationorigins.com/de/erneuerbare-energie-gemeinschaft-verbindet-die-stromproduktion-mit-regenerativer-landwirtschaft/ (accessed 4.10.25).

SDGs, 2025. United Nations Sustainable Development Goalds. https://sdgs.un.org/goals (accessed 5.28.24).

Simoiu, M.S., Fagarasan, I., Ploix, S., Calofir, V., 2022. Modeling the energy community members' willingness to change their behaviour with multi-agent systems: A stochastic approach. Renewable Energy 194, 1233–1246. https://doi.org/10.1016/j.renene.2022.06.004.

Soeiro, S., Dias, M. F., 2020. Motivations for Integrating a Renewable Energy Community: Evidence for Spain and Portugal. IEEE 1–6. https://doi.org/10.1109/EEM49802.2020.9221887.

Taylor, W.A., 2024. Konfliktrohstoffe, in: Gieg, P., Bobineau, J., Lowinger, T. (Eds.), Handbuch Demokratische Republik Kongo: Geschichte, Politik, Gesellschaft, Kultur. Frank & Timme GmbH, Berlin, 269–280. https://doi.org/10.57088/978-3-7329-9568-4_14.

Tishkov, S., Tleppayev, A., Karginova-Gubinova, V., Volkov, A., Shcherbak, A., 2022. Citizens' Behavior as a Driver of Energy Transition and Greening of the Economy in the Russian Arctic: Findings of a Sociological Survey in the Murmansk Region and Karelia. Applied Sciences 12, No. 3, 1460. https://doi.org/10.3390/app12031460.

Ullah, A., Nobanee, H., Ullah, S., Iftikhar, H., 2024. Renewable energy transition and regional integration: Energizing the pathway to sustainable development. Energy Policy 193, 114270. https://doi.org/10.1016/j.enpol.2024.114270.

van Bommel, N., Höffken, J.I., 2021. Energy justice within, between and beyond European community energy initiatives: A review. Energy Research & Social Science 79, 102157. https://doi.org/10.1016/j.erss.2021.102157.

Velini, A., Minetti, M., Bruno, S., Bonfiglio, A., Procopio, R., La Scala, M., 2025. Renewable energy communities virtual islanding: A decentralized service to improve distribution grid security. Sustainable Energy, Grids and Networks 42, 101700. https://doi.org/10.1016/j.segan.2025.101700.

Virah-Sawmy, D., Sturmberg, B., 2025. Socio-economic and environmental impacts of renewable energy deployments: A review. Renewable and Sustainable Energy Reviews 207, 114956. https://doi.org/10.1016/j.rser.2024.114956.