Interreg
Danube Region

Co-funded by
the European Union

NRGCOM

1.4 Assessment of possible low-cost infrastructure investments and developments

D1.4.1 Collection of development recommendations to optimise the functioning of energy communities

Joint Report

Content

(1) INTRODUCTION

Renewable Energy Communities (RECs) are critical in the transition towards a sustainable energy future. Optimizing RECs involves detailed strategic planning and the implementation of advanced technologies and infrastructures designed to maximize energy production, enhance efficiency, and ensure long-term sustainability.

This report delves into the essential strategies for optimizing the infrastructure of RECs. It highlights several critical areas: energy demand and production, energy storage and distribution, and community engagement. By addressing these aspects comprehensively, RECs can achieve higher levels of performance and contribute more effectively to the energy transition in the Danube region.

(2) METHODICAL GUIDE

The development and elaboration of the report D.1.4.1 "Collection of Development Recommendations to Optimize the Functioning of Energy Communities" is led by DIT, which acts as the activity leader. DIT is responsible for ensuring the comprehensive and timely completion of Deliverable D.1.4.1.

LEADERSHIP AND METHODOLOGY

DIT has elaborated the methodology to implement the activity A.1.4 “Assessment of possible low-cost infrastructure investments and developments”. The methodology was presented, discussed and agreed upon in the Launch Event in Budapest on 13 March 2024.

TECHNOLOGY WORKSHOP

A pivotal technology workshop was organized on 22 March 2024, which involved the participation of all project partners. The workshop included several key activities:

- **Interview Template Presentation:** An interview template was introduced to the participants. This template is designed to standardize data collection across all partners.

- **Technologies Discussion:** Various technologies relevant to energy communities were explained and discussed in detail.
- **Instructions for Filling In:** Clear instructions on how to complete the interview template were shared with all attendees, ensuring consistent and accurate data collection.

Template for National Reports

A standardized template for national reports was developed to serve as the primary input for Deliverable D1.4.1. This template includes:

- **Description of Load Profiles and Technologies:** Detailed descriptions of different load profiles and potential technologies to be implemented within energy communities.
- **Exemplary Answer:** An example answer was provided to illustrate how to complete the questionnaire accurately.
- **Questionnaire and Table:** The template contains a structured questionnaire and table that each partner is required to fill in, ensuring uniformity in data collection.

Involvement of Experts and Stakeholders

The elaboration of the reports involves active participation from experts and stakeholders. The process includes:

- **National Workshops:** Project partners (PPs) are encouraged to organize national workshops which can serve dual purposes:
    - ***Input Workshops:*** Participants provide input and support in completing the questionnaire.
    - ***Validation Workshops:*** PPs fill in the questionnaire first and then discuss the outcomes with workshop participants.
    - ***Combined Approach:*** A combination of input and validation workshops can also be employed for comprehensive feedback.
- **Direct Stakeholder Engagement:** In regions without established energy communities (e.g., Montenegro), relevant expertise can be gathered through direct stakeholder meetings or interviews.

Joint Workshop

A joint workshop was organized on 7 June 2024, with the participation of all partners. Key activities during this workshop included:

- **Presentation of National Reports:** Partners presented the outcomes of their national reports.
- **Presentation of Deliverable**: DIT presented the consolidated deliverable D1.4.1.

- **Discussion Opportunity:** The workshop provided a platform for discussing the outcomes, sharing insights, and addressing any queries or concerns.

INVOLVEMENT OF THE CONSORTIUM

The consortium's involvement is crucial for the successful completion of the national reports. The partners responsible for preparing national reports are:

- Hungary: STRIA & IMRO
- Czech Republic: JAIP
- Austria: FORSCHUNG
- Croatia: IRENA
- Slovenia: KSSENA
- Serbia: REDASP
- Romania: OER
- Montenegro: FORS Montenegro
- Germany: DIT
- Slovakia: NEK

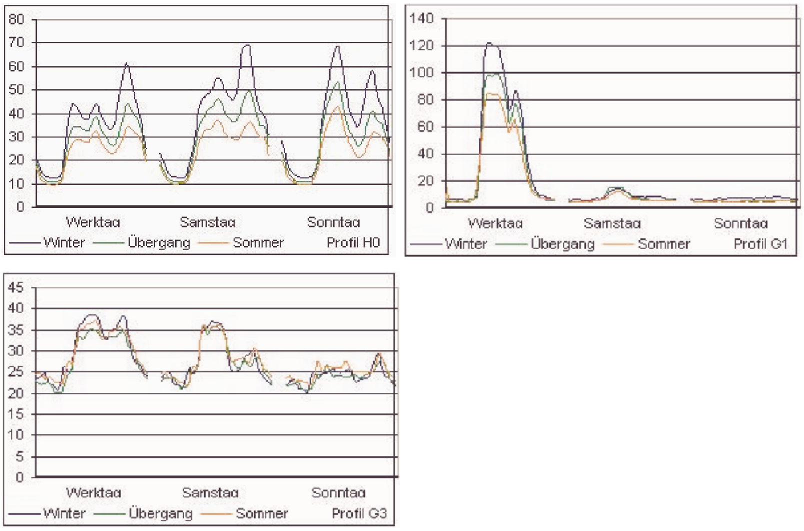
Additionally, the following partners are observers in the process:

- Bulgaria: PRA
- Moldova: AEER

This collaborative approach ensures a comprehensive and diversified collection of data and recommendations, facilitating the optimization of energy communities across different national contexts.

(3) ENERGY DEMAND

Understanding the energy consumption patterns of different consumers within the community is crucial for optimizing energy use and deploying appropriate power generation solutions. Energy consumers can be classified into three main load profiles: household, commercial, and industrial.



a) Household b) Commercial c) Industrial

Source: https://www.bdew.de/media/documents/1999_Repraesentative-VDEW-Lastprofile.pdf

Household Energy Load Profiles

Household energy consumption typically features daily peaks in the morning and evening, with more pronounced peaks on weekends. The average household power demand is between 2000 - 3000 kWh/year. Major energy consumers, such as heat pumps and electric cars, significantly influence these profiles. Time-resolved recording meters are often not installed, but new metering equipment is introduced with the adoption of rooftop photovoltaic (PV) systems, allowing detailed production as well as consumption analysis.

Commercial Energy Load Profiles

Commercial businesses generally operate from 08:00 to 16:00 on weekdays, resulting in energy peaks around midday. These businesses are often closed on weekends. Power demand may already be monitored with time resolution depending on the business and the energy demand. Heating provision via heat pumps or electromobility can amplify energy peaks.

Industrial Energy Load Profiles

Industrial profiles are highly specific and challenging to standardize. Power demand is typically high, often persistent even on weekends, and varies based on industry type. This demand impacts the grid, necessitating time-resolved analysis to ensure grid stability during peak loads.

(4) ENERGY PRODUCTION

In energy communities, a variety of technologies are employed to generate power and support heating networks, with Photovoltaic (PV) systems, wind power, and Combined Heat and Power (CHP) systems being the primary methods.

PHOTOVOLTAIC (PV) SYSTEMS

Photovoltaic (PV) systems convert sunlight directly into electricity using solar panels. These systems are a cornerstone of renewable energy in energy communities due to their numerous advantages. PV systems utilize sunlight, a renewable and abundant energy source, making them a sustainable choice. They are highly scalable, allowing for installation on various scales, from small rooftop systems on individual homes to large solar farms serving entire communities. Once installed, PV systems have relatively low maintenance and operating costs. Furthermore, they produce electricity without emitting greenhouse gases or pollutants, contributing to cleaner air and a reduced carbon footprint. In energy communities, PV systems are often integrated with energy storage solutions, such as batteries, to store excess energy generated during sunny periods for use during cloudy days or nighttime, ensuring a reliable power supply.

WIND POWER

Wind power harnesses the kinetic energy of wind through wind turbines to generate electricity. This technology is particularly beneficial in regions with strong and consistent wind patterns. Wind power is a clean, renewable resource that reduces dependence on fossil fuels. Modern wind turbines are highly efficient and capable of generating significant amounts of electricity with low operating and maintenance costs once installed. In energy communities, wind power can complement PV systems, providing electricity during times when solar generation is low, such as at night or during overcast conditions.

COMBINED HEAT AND POWER (CHP) SYSTEMS

Combined Heat and Power (CHP) systems, also known as cogeneration systems, simultaneously produce electricity and useful heat from the same energy source. These systems are particularly effective in supporting district heating networks, which distribute heat generated at a central location to residential and commercial bui ystems are highly efficient because they utilize the waste heat produced during electricity generation, which would otherwise be lost in conventional power plants. They can use various fuels, including natural gas, biomass, and biogas, making them adaptable to different energy sources. Additionally, CHP systems provide a reliable and continuous supply of heat and power, which is crucial for district heating networks. In energy communities, CHP systems play a vital role in reducing energy waste and improving overall energy efficiency. By providing both electricity and heat, they enhance the community's energy resilience and sustainability.

The integration of PV systems, wind power, and CHP systems in energy communities offers several benefits. Utilizing multiple renewable energy sources ensures a more stable and reliable energy supply. By generating power locally, energy communities reduce their dependence on external energy sources and improve energy security. These technologies collectively reduce greenhouse gas emissions and minimize the community's environmental impact. Additionally, local energy generation can lead to cost savings on energy bills and create local jobs in the renewable energy sector. By combining these technologies, energy communities can optimize their energy production, improve efficiency, and contribute to a more sustainable and resilient energy future.

Understanding the characteristics and optimization techniques for these systems is essential for aligning with the community's energy demand profiles.

(5) APPROACH TO OPTIMIZE OPERATION

Achieving optimal performance and sustainability in energy communities demands a comprehensive and multifaceted strategy. The NRGCOM partnership proposes an integrative approach that combines strategic planning, technological innovation, financial strategies, and community engagement.

Strategic planning forms the foundation of energy community optimization. It involves setting clear goals, identifying challenges, and developing a roadmap for achieving desired outcomes. Energy communities must assess current energy infrastructure, consumption patterns, and future needs through tools like energy audits and demand forecasting. Strategic planning ensures that optimization efforts are aligned with the community's objectives and resources, guiding decision-making processes and resource allocation effectively.

Technological innovation plays a pivotal role in enhancing the efficiency, reliability, and sustainability of energy communities. Advancements in renewable energy technologies, energy storage solutions, smart grid systems, and energy management software enable communities to harness clean energy sources more effectively, optimize energy distribution, and improve overall system performance. By embracing technological innovation, energy communities can reduce dependency on fossil fuels, minimize environmental impact, and adapt to evolving energy needs. This aspect is at heart of the current report and will be further detailed in the subsequent chapter called “Optimization recommendations”.

Financial strategies are essential for overcoming barriers to energy community optimization, such as high upfront costs and limited access to funding. Leveraging financial mechanisms like incentives, subsidies, grants, and community financing models can help offset initial investment expenses and improve the economic viability of renewable energy projects. Additionally, conducting cost-benefit analyses, exploring innovative financing options, and establishing partnerships with financial institutions can further support sustainability initiatives within energy communities.

Community Engagement is integral to the success and sustainability of energy community optimization efforts. Engaging community members fosters awareness, builds support, and generates momentum for renewable energy projects. Through participatory planning processes, educational initiatives, and collaborative decision-making, energy communities can empower residents to become active participants in shaping their energy future. Community engagement also promotes social cohesion, trust, and accountability, strengthening the resilience of energy communities in the face of challenges.

By integrating strategic planning, technological innovation, financial strategies, and community engagement, energy communities can optimize their infrastructure, enhance energy resilience, and accelerate the transition to a sustainable [illegible] future. This multifaceted approach ensures that optimization efforts are holistic, inclusive, and aligned with the needs and aspirations of the community.

(6) OPTIMIZATION RECOMMENDATIONS

The transition to sustainable energy systems within energy communities requires not only the adoption of renewable energy technologies but also their continuous optimization to ensure maximum efficiency, reliability, and sustainability. This chapter provides detailed optimization recommendations for each major technology field utilized within energy communities. By addressing specific strategies for photovoltaic (PV) systems, wind power, and combined heat and power (CHP) systems, this chapter aims to guide stakeholders in enhancing the performance and integration of these technologies. The recommendations presented here are based on the latest research, industry best practices, and practical insights gathered from existing energy communities. Implementing these optimization strategies will enable energy communities to better manage their resources, reduce operational costs, and achieve greater energy security and environmental benefits.

Photovoltaic (PV) Systems

Photovoltaic (PV) systems are a critical component of renewable energy communities, harnessing solar energy to generate electricity. There are two primary types of PV installations: rooftop PV systems and ground-mounted PV systems. Each type has distinct advantages and challenges that must be addressed to optimize their performance and integration within energy communities.

Types of PV Installations

Rooftop PV Systems:

Rooftop PV systems offer several advantages, making efficient use of existing roof space and reducing transmission losses. They provide a dual use of sealed surfaces found on residential or commercial building roofs, thus avoiding the need for additional land. However, these systems also face challenges, primarily stemming from the limited area available and potential suboptimal orientation due to roof design. The orientation of rooftop PV systems plays a crucial role in their performance. South-facing roofs are optimal for maximizing midday energy production, while east-west orientations can help cover energy needs in the morning and evening, ensuring more balanced energy generation throughout the day.

Ground-Mounted PV Systems:

Ground-mounted PV systems provide the advantage of optimized orientation and tilt, allowing for adjustments that maximize energy production. However, these systems face the challenge of requiring more land, which can be a significant obstacle to their implementation. Nonetheless, this challenge can be addressed through the use of Agri-PV systems, which combine solar panels with agricultural activities. By integrating solar panels with agricultural land use, Agri-PV systems enable dual land utilization, mitigating the land requirement issue and offering a more sustainable approach to land use.

Optimization Strategies

Panel Placement and Orientation:

To maximize sunlight exposure, panels should be oriented and tilted based on the location's latitude. Avoid shading to ensure optimal performance. Instead of a purely southern orientation, consider adjusting the tilt to shift peak energy production to the morning or evening, depending on energy demand patterns.

High-Efficiency Panels and Components:

Investing in high-efficiency panels and quality inverters is crucial. Over recent years, PV cell efficiency has surpassed 20%, significantly enhancing energy output.

System Sizing and Scaling:

The system should be sized according to energy needs and available roof space. It may be wise not to fully utilize all capacities immediately if investment costs are high due to market conditions or if the current energy requirement can be met with a smaller system.

Maintenance and Monitoring:

Regular cleaning and inspection of solar panels are essential maintenance tasks to ensure their optimal performance and longevity. It is crucial to regularly clean the panels and inspect them for any signs of physical damage. The frequency of cleaning depends on various factors, including the location of the panels, prevailing environmental conditions, and specific installation characteristics. Additionally, implementing real-time monitoring systems is highly recommended to continuously monitor the performance of the solar panels. These monitoring systems enable the timely detection of any issues or abnormalities, allowing for prompt intervention and maintenance to maintain optimal performance and maximize energy generation.

Energy Storage Integration:

Integrating battery storage systems is crucial for maximizing the utilization of solar energy in energy communities. These systems allow excess energy generated during peak sunlight hours to be stored for later use during periods of low or no production, such as nighttime or cloudy days. By storing surplus energy in batteries, energy communities can enhance their energy resilience, reduce dependence on the grid, and ensure a continuous and reliable power supply, even when solar generation is limited.

Grid Interaction and Net Metering:

Energy communities can leverage net metering as a valuable strategy for managing their energy output. With net metering, excess energy generated by solar panels can be fed back into the grid, allowing community members to earn credits or share energy within the community. Additionally, it is essential to ensure the reliability and safety of grid-tied systems. These systems should be equipped with mechanisms to safely disconnect during grid outages while also having the capability to operate autonomously as an island solution if necessary. By implementing these measures, energy communities can optimize their grid interaction, maximize energy utilization, and enhance overall energy resilience.

Wind Power

Wind turbines generate power based on wind conditions and feed into larger grids as 110 kV or above, supplying regions or large consumers. Local physical use can be challenging if grid operators redirect power to distant areas. Wind power can provide rural communities with new sources of income and funding for social initiatives.

Optimization Strategies

Site Selection and Assessment:

Conducting thorough wind resource assessments is crucial to identify ideal locations with consistent and high wind speeds. These assessments help determine the suitability of potential sites for wind turbine installation, ensuring optimal energy production.

Turbine Selection and Technology:

Matching turbines to the wind profile of the site is essential for maximizing energy capture. Selecting appropriate turbine sizes and capacities, along with utilizing advanced designs such as variable pitch blades, ensures that the turbines can effectively harness available wind energy.

Maintenance and Monitoring:

Implementing predictive maintenance and real-time monitoring systems allows for the anticipation of issues and tracking of turbine performance. By scheduling maintenance intervals during periods of low wind activity, downtime can be minimized, thereby reducing production losses and maximizing energy output.

Grid Integration and Energy Storage:

Ensuring grid compatibility is vital for seamless integration of wind power into the local grid infrastructure. Wind turbines should be capable of being controlled by the local energy grid operator to help stabilize the grid during fluctuations in wind energy production. Additionally, incorporating energy storage solutions, such as batteries, enables the management of variability and ensures a more consistent and reliable energy supply.

Aerodynamic Optimization:

Optimizing blade design and angle adjustment is key to enhancing the aerodynamic efficiency of wind turbines. Utilizing advanced aerodynamic designs and pitch control systems enables turbines to operate more efficiently across a wider range of wind conditions, maximizing energy capture and output.

Combined Heat and Power (CHP) Systems

When both power and heat are shared within an energy community, Combined Heat and Power (CHP) systems play a crucial role in optimizing energy utilization and enhancing overall efficiency.

Optimization Strategies

System Design and Sizing:

Conducting a thorough energy demand assessment is essential to ensure that the CHP system is appropriately sized to match the energy consumption profile of the community or the availability of fuel resources. By closely aligning system capacity with energy demand, energy communities can maximize the utilization of generated power and heat.

Fuel Selection:

Opting for cost-effective and environmentally sustainable fuels, such as biomass, biogas, or biomethane, is critical for the long-term viability of CHP systems. Assessing fuel availability and flexibility ensures that the chosen fuel source can reliably meet the community's energy needs while minimizing environmental impact.

Technology Selection:

Choosing appropriate prime movers and efficiency enhancements is key to maximizing the overall efficiency of CHP systems. Utilizing advanced technologies and combined cycle systems improves energy conversion efficiency, resulting in higher power and heat output for the same amount of fuel input.

Thermal Energy Utilization:

Implementing heat recovery systems and thermal storage solutions allows energy communities to capture and store excess heat generated by the CHP system for later use. This enhances overall energy efficiency and provides flexibility in meeting fluctuating heating demands.

Control and Monitoring Systems:

Implementing automated controls and performance monitoring systems enables energy communities to optimize CHP system operation in real-time. By tracking key performance indicators and adjusting system parameters as needed, communities can maximize energy production and minimize operating costs.

Maintenance and Reliability:

Prioritizing preventive maintenance and condition monitoring practices is essential for ensuring the long-term reliability and efficiency of CHP systems. By identifying and addressing potential issues proactively, communities can reduce the risk of downtime and optimize system performance over its operational lifespan.

Economic and Financial Optimization:

Conducting cost-benefit analyses and leveraging financial incentives are crucial steps in optimizing the economic and financial aspects of CHP system deployment. Communities should evaluate the economic feasibility of CHP projects, considering factors such as upfront capital costs, operational expenses, and potential revenue streams from electricity sales. Additionally, taking advantage of opportunities to produce electricity when market prices are high and during periods of low wind activity enhances the financial viability of CHP systems.

Environmental and Regulatory Considerations:

Implementing emission controls and adopting sustainability practices are essential for minimizing the environmental impact of CHP systems and ensuring compliance with regulatory requirements. By reducing emissions and implementing sustainable practices, energy communities can contribute to environmental conservation and meet regulatory standards for air quality and emissions.

OPTIMIZATION OF INFRASTRUCTURE

The optimization of REC infrastructure is a multifaceted endeavor that encompasses various aspects of energy planning, technology integration, storage solutions, grid management, energy efficiency measures, community engagement, and regulatory compliance.

Comprehensive Energy Planning:

Conducting energy audits and demand forecasting are essential components of comprehensive energy planning. Energy audits provide insights into current consumption patterns, identifying areas for improvement and efficiency gains. Demand forecasting allows for the anticipation of future energy needs, facilitating strategic capacity expansion and resource allocation.

Integration of Renewable Energy Sources:

REC infrastructure optimization relies on the integration of diverse renewable energy sources, including solar PV, wind turbines, biomass, and hydro power. This diverse energy mix helps stabilize the grid and cater to the specific energy requirements of different consumer segments. Site assessment and scalability considerations ensure the selection of suitable locations and the design of systems that can be easily expanded to meet growing demand.

Advanced Energy Storage Solutions:

Advanced energy storage solutions, such as battery, chemical, and thermal storage systems, play a crucial role in REC optimization. These systems store excess energy generated during periods of high production for use during low production periods, ensuring continuous energy supply. Hybrid storage systems, which combine different storage technologies, offer enhanced flexibility and efficiency in energy management and distribution.

Sector Coupling:

Sector coupling involves integrating different energy sectors, such as heat and mobility, to optimize energy utilization. Heat pump and power-to-heat technologies utilize renewable power for heat generation, particularly in regions with limited access to other heat sources. Similarly, electric mobility and alternative fuel options like hydrogen or green methane are leveraged for transportation purposes, reducing dependence on fossil fuels.

Smart Grid and Microgrid Technologies:

Smart grid and microgrid technologies enable real-time monitoring and control of energy flows within the REC infrastructure. These technologies facilitate demand response mechanisms, decentralized energy management, and the development of microgrids, thereby balancing supply and demand and enhancing grid resilience.

Energy Efficiency Measures:

Implementing energy efficiency measures, such as building retrofitting, deployment of smart appliances, and adoption of energy management systems, is crucial for optimizing energy consumption within the REC. These measures improve efficiency, reduce energy waste, and contribute to overall sustainability goals.

Community Engagement and Education:

Community engagement initiatives, including awareness campaigns, participatory planning processes, and training programs, are essential for fostering a culture of sustainability and building local expertise in renewable energy systems. Engaging community members in REC initiatives increases awareness, encourages participation, and fosters a sense of ownership and responsibility.

Financial and Regulatory Support:

Financial incentives, subsidies, and regulatory frameworks are instrumental in supporting REC infrastructure optimization efforts. Incentives and subsidies help reduce costs and enhance the financial viability of renewable energy projects, while regulatory frameworks ensure compliance with standards and regulations. Community financing mechanisms further facilitate REC development by providing access to funding and investment opportunities.

(7) CONCLUSION

The current report aims at providing development recommendations on optimizing Renewable Energy Communities and underscores the importance of a multifaceted approach encompassing strategic planning, technological innovation, financial strategies, and community engagement. By addressing these key areas, RECs have the opportunity to significantly enhance their energy resilience, reduce costs, and make substantial contributions to sustainable development goals.

Throughout the report, various chapters have delved into critical aspects of REC optimization, including the integration of renewable energy sources, advanced energy storage solutions, smart grid technologies, energy efficiency measures, and community engagement initiatives. These chapters have provided valuable insights into the diverse strategies and technologies available for improving the efficiency and reliability of REC infrastructure.

By leveraging diverse renewable energy sources and implementing advanced storage solutions, RECs can ensure a continuous and reliable energy supply while minimizing environmental impact. Smart grid technologies enable real-time monitoring and control of energy flows, enhancing grid stability and resilience. Energy efficiency measures, coupled with community engagement and education, promote a culture of sustainability and empower local communities to actively participate in REC initiatives.

Furthermore, the report highlights the importance of financial and regulatory support in facilitating REC optimization efforts. Incentives, subsidies, and regulatory frameworks play a crucial role in reducing costs, enhancing financial viability, and ensuring compliance with standards and regulations.

In essence, the strategies outlined in the report not only improve the efficiency and reliability of energy systems within RECs but also promote the development of more sustainable and resilient communities. By implementing these strategies, RECs can take significant strides towards achieving their sustainability goals and contributing to a cleaner, greener future for generations to come.