European Commission

Navigating Technology Types for Rural Energy Communities

THE RURAL ENERGY COMMUNITY ADVISORY HUB

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1. EMPOWERING RURAL ENERGY COMMUNITIES

Building sustainable solutions for local energy independence

Imagine if your local community could generate its own clean and renewable energy. Are you equipped with the tools, knowledge, and means to make it a reality?

This guidance document serves as a comprehensive resource designed to empower your community in making well-informed decisions when it comes to developing renewable energy projects. Its primary goal is to provide you with practical guidance, step-by-step instructions, and valuable insights to support and inspire you throughout the entire process. Whether you are just starting to explore the potential of renewable energy or already have a project in mind, this document will showcase a range of options available to us and guide you in assessing, planning, and implementing renewable energy technologies.

It builds upon a collection of published guidance documents, which cover topics such as setting up rural energy communities, financial management, engaging with your local community, and providing information on national policy and legal frameworks across the 27 Member States in the European Union. Furthermore, you'll have the opportunity to learn from the success stories of other rural energy communities that have become European Best Practice Rural Energy Communities, serving as inspirational examples to fuel your own community's vision. By leveraging the tools and knowledge presented here, you can harness the potential of renewable energy and create a sustainable future for your community with a variety of benefits.

Key benefits of developing community-based renewable energy include:

- Lower carbon footprint
- Financial security through long-term protection from rising energy costs
- Reinvestment opportunities for community development schemes

Additionally, generating your own energy can offer various advantages such as:

- Profit-making from selling excess energy to the national grid
- Increased energy independence and resilience
- Utilization of available agricultural land (e.g., animal grazing and arable land) and community spaces (e.g., roofs of homes, schools, businesses, and community centres) to enhance and diversify energy production

This document will delve into the main energy production technologies available to energy communities like yours, including solar PV, biomass, wind, and hydropower. Through detailed explanations and examples, we will explore how each technology can be implemented and the potential benefits they bring to your community. To facilitate your informed evaluation in assessing the economic feasibility of renewable energy projects and their competitiveness relative to traditional sources, this guidance refers to the Levelized Cost of Electricity (LCOE). The LCOE represents the average expenditure incurred for producing each unit of electricity (measured in kilowatt-hours) from a renewable energy source throughout its operational lifespan. It encompasses capital costs, operational and maintenance expenses, fuel costs (if applicable), and anticipated energy output.

Thanks to technological developments over the past decade, communities like yours now have the opportunity to enhance and diversify the use of available agricultural land. For example, raised solar PV allows arable or grazing land to be used for energy generation, increasing profitability and sustainability for farmers in rural areas. Additionally, rural areas have a significant advantage over urban areas for certain technologies such as biogas, as waste feedstocks can often be utilized to generate energy.

With the guidance and insights presented in this guidance document, you can embark on a journey toward a sustainable future, where your community actively contributes to clean energy production and enjoys the economic, environmental, and social benefits it brings.

2. PLANNING AND DEVELOPING YOUR RENEWABLE ENERGY PROJECT

Step 1: Developing the idea

- **Develop the vision** and define why you want to undertake the community-led project. For more information on setting out a viable vision and methodological planning approach, visit CARES: Guide to developing community-led local energy planning.
- **Create your business model** to help plan out your vision. For additional guidance, refer to the RECAH Guidance Document: Obtaining and Managing Finances.
- **Seek advice** on the type of renewable energy technology you have chosen from experts and successful projects implemented by groups or businesses like your energy community.
- **Communicate** as early as possible with residents and the wider community to gain support for the project.
- **Assess potential sites** based on key factors to determine the feasibility of implementing and operating the selected renewable energy technology.
- **Initial viability** to be determined based on contacting suppliers to receive cost estimations and the amount of electricity that will be generated to assess the potential of the selected site.

Step 2: Steps for Energy Project Development

- **Establish a legal entity** through the nationally determined criteria of an energy community as either a citizen or renewable energy community. For more information, refer to the RECAH Guidance Document: Creating value and engaging citizens in the energy transition.
- **Secure the site(s)** by obtaining legal agreements to use the site where the renewable energy technology will be installed.
- **Secure initial funding** by identifying funding options to support feasibility work.
- **Feasibility study** to be conducted to assess the technical, financial, and regulatory viability for the site(s).
- **Secure project funding** by obtaining capital funding through a financial agreement (for more information refer to the RECAH Guidance Document: Obtaining and Managing Finances).
- **Financial appraisal** to account for the estimated expenditure and income. A useful tool is the CARES financial model.

Step 3: Implementation of the Energy Project

- **Applications** for planning permission (if required) and for connection to the national grid with your Distribution Network Operator (DNO) (if required).
- **Procurement** to finalise the scope and amount of all quotations, then confirm the suppliers/installers that will be used. Procure the renewable energy technology and services required to install.
- **Construction** of renewable energy technology by confirming all orders and contracts.
- **Financial close** to defining the point where the money is released to implement and construct the project.

Step 4: Operation of the Energy Project

- **Repayment of loans** and secure any additional capital funding where required.
- **Community benefit agreement** to be set up to secure an index linked to community benefit payments for the life of the project.
- **Operation** through ensuring that effective management and maintenance regimes are in place for the life of the project to keep the renewable energy installations operating successfully. In addition, there is the need to manage finances and ensure there is fair distribution of income, and any other financial liabilities.
- **Plan for decommissioning or refurbishment** based on the type of renewable energy installation. Typically, installations are removed at the end of their productive life or when they no longer generate electricity.

3. ESSENTIAL QUESTIONS FOR YOUR RURAL ENERGY COMMUNITY

When beginning to plan for the types of renewable energy technologies, it is helpful to ask yourself the following questions. These indicative questions are designed to prompt you to consider the variety of options available for your rural energy community. The aim is to assist you in deciding on the most suitable technologies, attract support and identify locations at an early stage:

Community Acceptance and Benefits:

- Would the installation of this technology be welcomed by the community, and how can we increase acceptance?
- What are the benefits and drawbacks of the different technologies?
- What are the potential job creation and economic development opportunities associated with the implementation of renewable energy projects in our community?

Financial and Legal Support:

- Does our local municipality provide financial support and/or resources (such as building space or feedstocks) for the project and, if so, what is feasible to install?
- Are there any specific subsidies and funding opportunities available for particular technologies?

Resource Assessment and Feasibility:

- What is the availability of renewable energy resources in our area (such as wind, solar, biomass)?
- Have we approached local farmers' organisations to determine if there are resources available to facilitate energy production, such as biomass from agriculture waste, in the area?
- Can we conduct a feasibility to assess the efficiency of technologies in the given locations and estimate the annual financial returns?
- How do the cost-benefit comparisons of various technology and site options align with the goals and resources of our rural energy community?
- What is the optimal scale at which our energy community can install renewable energy technologies to maximize efficiency, cost-effectiveness, and community impact?

Engagement and Collaboration:

- How can we effectively engage and educate our community members about the benefits and opportunities associated with renewable energy technologies?
- Are there potential partnerships or collaborations with local businesses, organizations, or government entities that can support the development of our renewable energy projects?

Planning and Implementation Considerations:

- What are the regulatory and permitting requirements that need to be considered when implementing renewable energy projects in our local area?
- How can we ensure the long-term maintenance and sustainability of the renewable energy systems within our community?
- Are there opportunities for community members to participate in the planning, decision-making, and ownership of the renewable energy projects?
- How can we monitor and track the environmental impact and performance of our renewable energy systems to ensure they align with sustainability goals?

By considering these questions and conducting thorough assessments, you can make informed decisions that will guide the planning and implementation of renewable energy projects in your community. The answers to these questions will help shape the direction and success of your initiatives, ensuring that you choose the most appropriate technologies and locations for your rural energy community.

4. SOLAR PV FACTSHEET

Solar PV

Solar photovoltaic (PV) panels are composed of cells made from layers of semi-conducting material. They generate electricity when light shines on the material. Solar PV has emerged as a crucial renewable energy technology, with increasing adoption worldwide. They don't need direct sunlight to work and can operate on cloudy days, however more light results in higher levels of electricity generation. Solar PV is well-suited to rural areas with greater amounts of space and higher availability of suitable sites compared to urban areas, but rooftop-mounted solar PV also holds significant potential in urban areas.

Benefits

Solar PV is well-suited to rural areas, offering several benefits for farmers and landowners:

- Unused roof space from farm buildings or unproductive land can be utilized for energy and income generation.
- Solar panels generate energy locally, saving costs associated with running distribution cables over long distances for electric gates, pumps, or sensors.
- Rising electricity costs have been affecting farmers and their profitability, but solar PV provides an opportunity to reduce energy expenses.
- Solar panels mounted on farm building roofs typically do not require planning permission and are relatively simple to install.

Costs

- The Levelized Cost of Electricity (LCOE) for PV systems varies depending on the type of systems and solar irradiation, ranging from 3.12 to 11.01 €cent/kWh (excluding VAT[1]).
- The specific costs of systems, currently ranging from €530 to €1600/kWp, have been consistently decreasing, especially for larger systems.
- In 2021, the average total installed costs for utility-scale solar PV varied greatly among the reported countries. The lowest was in Austria, where it was €614/kW, while the highest was in Croatia at €1,046/kW. It's also worth noting that these cost ranges become even more diverse when compared on a global scale[2].
- Once installed, maintenance and servicing costs for Solar PV installations are low in comparison to other renewable energy technologies.

Types

- Crystalline polysilicon remains the dominant technology for PV modules, with over 95% market share.
- New technologies, such as monocrystalline wafers that are more efficient are expanding their market share.
- More efficient cell design, such as PERC (with a market share of almost 75%), and even higher efficiency designs using technologies such as TOPCon, heterojunction and back-contact solar panels) are emerging in the market.

Application for Rural Areas

- **Standalone solar PV**: Individual equipment powered by Solar PV, such as gate motors, water pumps, floodlights or similar applications, typically used where the energy-consuming device is far from other energy connections.
- **Roof-Mounted Solar PV Systems**: Installing solar panels on suitable buildings, including agricultural structures with a 10-15° roof pitch, can generate significant amounts of energy for individual households or communities.

[1] VAT: Value Added Tax

[2] For more information on renewable energy cost comparisons visit: IRENA Power Generation Costs 2021

Households can install solar panels on roofs, enabling self-consumption of the energy at an individual or community level.

- **Solar Farms and Parks:** Solar farms have the capacity to be combined with other types of farming, such as animal grazing, which can be initiated by agricultural businesses or community groups. Solar parks are eligible for financial incentive schemes such as Power Purchase Agreements (PPAs).

Considerations

- **Space is a key consideration.** Rural areas benefit from having more available space than urban areas, and therefore can up-scale to large systems with higher energy generation.
- **Orientation and availability of sunlight.** While south-facing roofs are ideal for maximum energy generation, a detailed assessment during the planning stage is necessary for roofs facing other directions.
- **Time-of-day consumption.** Solar PV generates energy during the day, necessitating storage solutions for consumption after dark.

Policy Support

- Solar PV has been driven by strong policy support with various types of policy available depending on the Member States national laws. Examples of supportive schemes include energy auctions, feed-in tariffs, net-metering, and contracts for difference. For more details and useful links, refer to RECAH Guidance Document: National Legal and Policy Frameworks
- The European Commission has significantly increased the renewable energy target for 2030 to 45% through the REPowerEU plan, leading to a greater push for solar PV installations.
- In line with this target, the European Commission has set a goal of achieving 600 GW of solar PV generation by 2030 as part of the EU Solar Energy Strategy.
- To encourage Member States to support initiatives for installing and operating solar PV systems, there have been a variety of policies and incentives in place. For more details and useful links, refer to RECAH Guidance Document: Obtaining and Managing Finances.

Success story! EnGreen (RECAH Network Member / Technical Assistance receiver)

Figure 1: Val. Zer project (Source: EnGreen[3])

EnGreen, a visionary Italian consultancy founded in 2019, launched the Val. Zer (Valley at Zero Emission) Project[3], a renewable energy community (REC) located in the small town of Notaresco, Teramo in central Italy. Their mission is to spearhead rural development through creating a thriving energy community that relies on clean and sustainable sources of power.

The journey began with the establishment of a citizen association, which currently includes ten households. Out of these households, five are prosumers, meaning they generate clean energy for self-consumption and share any surplus with fellow members. With a current capacity of 32 kW of photovoltaic (PV) panels and 75 kWh of lithium storage, EnGreen aims to continue expanding the community. They identified a key motivating factor for community interest was the potential for substantial energy bill savings. Private owners of solar plants within the community can not only consume the energy they generate but also contribute surplus power to the local grid, benefiting the entire neighbourhood. Notably, the project has witnessed an increasing level of engagement from the local authority. In contrast to the project's early stages, the local government is now actively seeking involvement and expressing a desire to take ownership. This newfound support has inspired EnGreen to explore the possibility of replicating the project in other neighbourhoods, allowing even more communities to experience the benefits of renewable energy and cost savings.

[3] For more information visit EnGreen.

Initially, Engreen provided financing for one of the five solar plants installed, contributing 20% of the total investment. Subsequently, 60% of the funding was secured through a national grant, with the remaining 20% being contributed by the community members. Their aim is that not more than 50% of the project's funding will go to prosumer investments, with 30% allocated to the members consuming the energy, and 10-20% set aside as contingency funds for other investments and activities. This surplus money can be utilized in various non-energy activities, thereby benefitting the community at large. Examples include initiatives such as acquiring a school bus, revitalizing the local square, enhancing public lighting infrastructure, providing support to the most vulnerable families in the village, or acquiring processing machines for maize and olive oil production.

EnGreen envisions phase 2 of the Val.Zer. Project, which involves the implementation of a district heating system powered by a biomass combined heat and power (CHP) engine. This innovative system will fulfil the thermal needs of the entire community, taking them a step closer to achieving complete energy self-sufficiency through local renewable sources. EnGreen's remarkable progress in rural solar PV not only benefits the residents, but also inspires others to embark on similar endeavours. By showcasing the potential of renewable energy and community-driven initiatives, EnGreen is fostering a greener and more prosperous future for rural areas. Their success story serves as an inspiration for energy communities at an early development stage[4] and paves the way for a widespread adoption of renewable energy technologies in rural communities worldwide.

5. WIND TURBINES FACTSHEET

Wind Turbines

Wind turbines offer numerous benefits as a clean and sustainable source of energy. This factsheet provides information on the benefits, costs, types, application for rural areas, considerations, and policy support related to wind turbines.

Benefits

- Wind energy generation is clean and sustainable, producing zero carbon emissions, pollution, or waste during operation. However, it's important to recognise that the overall life cycle of a wind energy system includes stages like development and manufacturing, which may have some environmental impacts. These impacts, such as land use changes and emissions from manufacturing, are relatively lower compared to conventional energy sources.
- Wind turbines are becoming increasingly flexible, capable of operating at lower wind speeds and aligning with energy demand. The wind industry constantly improves its materials, with 85-90% of a turbine being recyclable[5], contributing to sustainability. It is important to note that recycling rates and practices for wind turbines may vary depending on national waste legislation, which can differ among EU Member States.[5]
- Wind farms bring economic benefits to local areas, including taxes and job creation, making them a valuable asset to rural communities.
- Collective ownership models allow for revenue sharing at the local level, giving citizens a stake in their energy supply.

Costs[6]

- Onshore wind power plants in 2021 have specific plant costs ranging between €1400 and €2000 per kilowatt (kW), resulting in a Levelized Cost of Electricity (LCOE) ranging from 3.94 to 8.29 €cent/kWh.

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[4] See Guidance Document on Obtaining and Managing Finances for more information.

[5] Information cited from: Sustainability | WindEurope

[6] Levelized Cost of Electricity: Renewables Clearly Superior to Conventional Power Plants Due to Rising CO2 Prices - Fraunhofer ISE

- Between 2010 and 2021, the worldwide average total installation cost for onshore wind saw a significant decrease of 35%. This represents a drop from approximately €1,736/kW to €1,126/kW for the average cost of installation[2].
- Offshore wind power plants also have decreasing costs, with electricity production costs ranging from 7.23 to 12.13 €cent/kWh. The specific plant costs, including the connection to the mainland, range from €3000 to €4000 per kW.
- Wind energy costs are competitive with other forms of energy generation, and further cost reductions are expected with technological advancements and economies of scale.

Types

- **Onshore wind farms**: Currently the most common form of wind farms, are located at least 3 kilometres from the coast, utilising terrestrial air currents for energy generation. In 2021, 93% were onshore systems, while 7% were offshore.
- **Nearshore wind farms**: These are also located on land and must be within 3 kilometres of the coast. These systems harness both terrestrial winds and sea winds for energy production.
- **Offshore wind farms**: Wind turbines are built in the open sea several miles from the coast, benefit from stronger and more consistent sea winds, resulting in higher energy generation compared to land installations.

Application for Rural Areas

- Rural communities can participate in larger commercial wind farm development to reduce costs and resource burdens for your community.
- Generate income for your community through cooperative or community funds, allowing for reinvestment in existing homes, improvements to parks and social centres, or investment in new renewable energy projects.
- Land requirements: Although 20 turbines cover an area of 240 acres, they occupy only 1% of the ground-level space, allowing the remaining land to be utilized for agricultural purposes such as growing crops or grazing.
- Wind farms bring economic benefits like taxes, to the places they are located. They provide jobs and investments in local, often rural communities.

Considerations

- **Site location is critical** to minimize impacts on wildlife and habitats. Planning and design stages should consider context-specific geo-environmental conditions.
- **Adequate space is necessary** to ensure each turbine has uninterrupted exposure to wind, with a suitable connection to the national grid and access for construction traffic.
- **Residents may also have concerns** over the appearance of the turbines, noise levels, falling house prices and impacts on tourism. Your group should be able to hold public meetings to resolve conflicts of interest.

Policy Support

- Various policies support wind power deployment, providing opportunities for your energy community. These include feed-in tariffs, auctions, Contracts for Difference (CfD), power purchase agreements (PPAs), and other forms of subsidy or grant support.
- For more detailed information on how to access policies, refer to RECAH Guidance Document: Obtaining and Managing Finances.

Success story! Éolienne citoyenne de Chamole (RECAH Best Practice)

Figure 2: Rural Energy Community Éolienne citoyenne de Chamole[7]

In France, Chamole, Éolienne citoyenne de Chamole[7] is a remarkable example of wind power being utilised by a rural energy community. It has been showcased as a RECAH Best Practice. This citizen-driven project features six wind turbines. Jointly owned by the local commune, a citizen cooperative, a territorial tool, a regional company, and a national fund, this initiative has brought together over 600 citizens through 40 investment clubs. The citizen cooperatives receive annual returns, and profits are reinvested in future projects. Educational efforts aim to promote the benefits of wind turbines and dispel misconceptions. Through this inspiring initiative, Chamole has become a beacon of renewable energy and community collaboration.

The journey to establish the citizen-owned wind turbine was not without its challenges. The project required a substantial investment of €5 million, which encompassed various expenses such as studies, road infrastructure, and connections. Approximately 20% of the work was carried out by local companies, reinforcing the project's positive impact on the community's economy. The financing of the project involved co-owners contributing €650,000, while the remaining funds were secured through a bank loan. The turbines boast a nominal power of 3000kW each, and to operate at maximum efficiency, the turbines require a wind speed of 12.5m/s, approximately 45km/h. However, they are designed to function even below this threshold, with a minimum wind speed of 8km/h necessary for rotation.

A single wind turbine, with an annual generation capacity of 6000 MWh, is capable of meeting the electricity needs of numerous households. To illustrate, consider an average European Union household, which typically consumes 3 MWh of electricity per year. With this level of consumption, one wind turbine could theoretically sustain about 2000 households annually. Éolienne citoyenne de Chamole takes this potential to new heights by owning and operating six such wind turbines. Each turbine is expected to produce between 6 to 7 million kWh annually, equivalent to 6000 to 7000 MWh. Collectively, these six turbines can generate a substantial 36,000 to 42,000 MWh per year. As a result, they have the capacity to provide electricity for approximately 12,000 households annually, significantly boosting the region's renewable energy supply.

In terms of allocation of profits, the community ensures that at least 60% of the profits remain within the organization, supporting the advancement of additional projects. This retention of profits directly benefits the community. Although the residents do not experience a direct decrease in their energy tariffs, they receive financial assistance aimed at reducing their energy bills. This assistance helps alleviate the financial burden of energy costs for the residents. In addition, there is also strong emphasis on promoting the wind turbine park and the citizen turbine community as educational tools to showcase the advantages of wind turbines and renewable energy. The cooperative actively organizes educational visits for schoolchildren, elected representatives, and others to raise awareness and educate about these benefits. In order to spread knowledge and understanding, educational panels are placed along the path within the park, which is open to the public in France. This encourages public engagement and helps create a more informed and environmentally conscious society.

[7] For more information, visit Energie Partagee

6. BIOMASS AND BIOGAS FACTSHEET

Biomass and biogas

Biomass and biogas present a significant opportunity for energy communities in rural areas to utilize waste materials as both an energy source and a source of income. Biogas and biogas-based electricity, derived from the breakdown of organic matter such as food waste, animal waste, and agricultural residues, offer environmentally friendly and renewable energy solutions. By capturing the gases released during natural decay and using them as an energy source, your community can contribute to the energy transition while generating reliable income streams.

Benefits

- Producing biogas/biomass fits into the sustainability cycle of managing agricultural waste.
- Waste products such as animal manure, municipal rubbish or waste, plant material, food waste or sewage and other agricultural residues can be used to produce biogas.
- Biogas can be:
  - used as is to produce heat, for example as an energy source for cooking.
  - can be ‘upgraded’ into biomethane for use as vehicle fuel or for injection in the natural gas grid
  - used to produce electricity (often in combination with heat, called ‘co-generation’)

Costs

- The Levelized Cost of Electricity (LCOE) for biogas varies from 8.45 to 17.26 €cent/kWh.
- The Levelized Cost of Electricity (LCOE) for solid biomass plants is slightly lower, ranging from 7.22 to 15.33 €cent/kWh.
- Feedstock costs are an important factor for biomass, as some are more expensive than others to create energy from. The cheapest feedstocks to utilise depend on the context of availability feedstocks in your area, especially considering high costs of transport. For example, it would be most cost-effective to use agricultural residues (e.g. corn stover and wheat straw) and waste products (e.g. manure and municipal waste). For more information, refer to IEAs: Sustainable supply potential and costs.

Types

Biogas and biomethane are two distinct terms used in the context of anaerobic digestion of organic matter. Biogas is a mixture of gases, including methane (CH_4), carbon dioxide (CO_2), and small quantities of other gases, produced through the anaerobic digestion process. Biomethane, on the other hand, refers specifically to biogas that has undergone a purification process to remove CO_2 and contaminants, resulting in a higher concentration of methane. When considering the energy needs of a rural energy community, simple biogas production is often a more practical and cost-effective option compared to biomethane. However, there are additional benefits as biomethane can be exported to the national grid, allowing the sale of excess supply and generating income.[8] Biodigesters, which are oxygen-free containers or tanks facilitating the anaerobic digestion of organic waste, are well-suited for rural energy communities. These biodigesters can vary in production capacity, ranging from small-scale (100 cubic meters per hour [m3/h]) to medium-scale (250 m3/h) and large-scale output flow rates (750 m3/h).

The methane content in biogas typically falls between 45% and 75% by volume, with the remaining gases comprising CO_2 and other components. Figure 3 provides an illustration of the various production pathways for both biogas and biomethane. However, it is important to note that the upgrading process, which removes CO_2 and contaminants, accounts for the majority (90%) of worldwide biomethane production.

[8] For more information on successful biomethane initiatives: https://www.bright-renewables.com/projects/

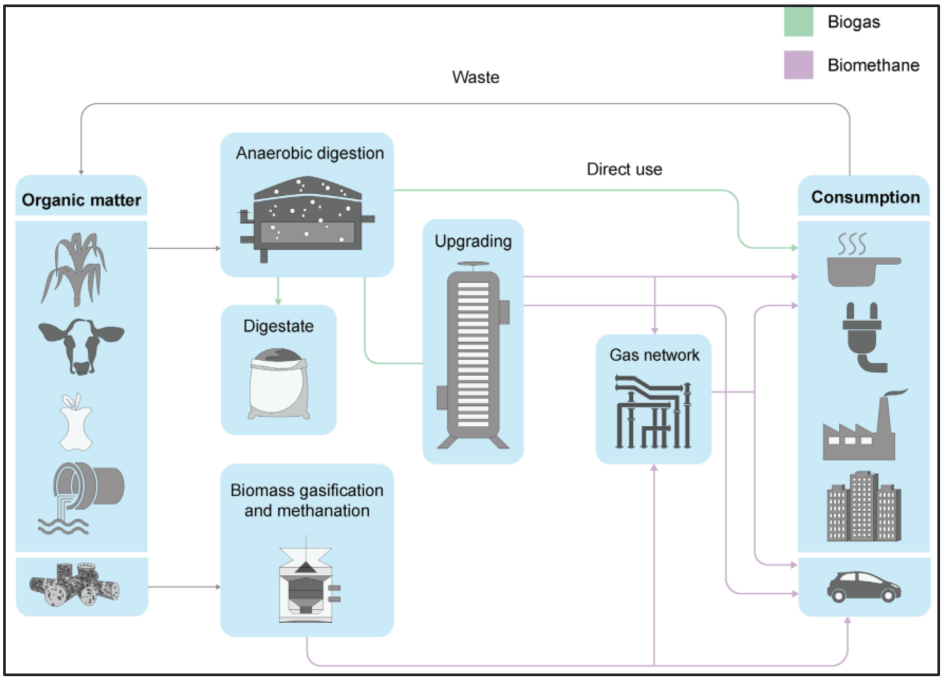

Figure 3: Production pathways for biomass (organic matter), biogas, and biomethane (IEA, 2020)

Application for Rural Areas

- **Heating Chicken Coops and Barns**: Biogas can be used to provide heat for chicken coops, barns, and other agricultural buildings. By utilizing biogas as a heating source, rural communities can improve the comfort and well-being of their livestock while reducing reliance on fossil fuel-based heating systems.
- **Cooking Gas**: In rural areas, biogas can serve as a clean and renewable alternative for cooking. By utilizing biogas for cooking purposes, communities can reduce their dependence on traditional cooking fuels such as wood, charcoal, or liquefied petroleum gas (LPG). This not only reduces environmental impact but also improves indoor air quality.
- **Electricity Generation**: Biogas can be used as a fuel for generating electricity. By utilizing biogas in generators or combined heat and power (CHP) systems, rural communities can produce their own electricity, reducing reliance on grid power and promoting energy self-sufficiency. This electricity can be used to power various electrical appliances, machinery, and lighting in homes, farms, and community buildings.
- **District Heating Systems**: Biogas can also be utilized in district heating systems for water and space heating in rural communities. By incorporating biogas-based heating systems, rural communities can meet their hot water and space heating needs in an efficient and environmentally friendly manner. Biogas-powered district heating reduces reliance on fossil fuels, promotes sustainability, and provides reliable and affordable heating solutions.
- **Fuelling Vehicles**: Biogas, when compressed into biomethane, serves as a versatile vehicle fuel, including for powering farm machinery. By utilizing biomethane derived from biogas, rural communities can effectively fuel their vehicles and farm equipment in an environmentally friendly manner.

Considerations

- The cultivation of specific energy crops solely for energy production instead of food has raised concerns about land-use impacts and environmental changes. It is important to assess whether to grow specialized energy crops or utilize residues from existing crop yields in alignment with your community's vision.

- The availability of feedstocks determines the potential for biogas production. Consider the four broad feedstock categories and their quantities: crop residues, animal manure, organic fraction of municipal solid waste, and wastewater sludge. Collaborate with farmers and local authorities to explore options for obtaining suitable feedstocks. Key feedstock categories:
    - **Crop residues:** Residues from harvesting coarse grains such as wheat, maize, rice and oilseeds such as sugar cane, soybean, sugar beet.
    - **Animal manure**: Obtained from livestock such as cattle, pigs, sheep and poultry.
    - **Organic fraction of municipal solid waste**: Food and green waste (i.e., leaves and grass), paper, cardboard, and wood that is not utilised can be used. Talk to your local authority about exploring options to collaborate to receive this type of feedstock.
    - **Wastewater sludge**: Semi-solid organic matter recovered in the form of sewage gas.
- The efficiency and energy production levels of your rural energy community will vary based on the type of feedstock(s) you obtain. For more information on feedstock efficiencies, visit the International Energy Agencies factsheet.

Policy Support

- Europe is the largest producer of biogas globally. Two-thirds of Europe's biogas plant capacity comes from Germany, which is the largest market and centre of bio-energy production.
- EU policy is centred around the use of crop residues, sequential crops, livestock waste and capturing methane from landfill sites – omitting the use of specific energy crops due to conflicts of interest regarding land use change from agriculture to energy production.

Success story! Wildpoldsried Energy Community (RECAH Best Practice)

The Wildpoldsried Energy Community[9], located in the Allgäu region of Bavaria, Germany, has emerged as a shining example of how local residents can come together to harness renewable energy sources and create a sustainable future. With a population of approximately 2,600 people and a commitment to environmental stewardship, the community has successfully implemented a range of bioenergy elements to meet their energy needs. The community's dedication to sustainable energy is evident in their diverse portfolio of renewable technologies. Over 3,000 solar panels and 11 wind turbines, harnessing the power of the sun and wind to generate clean electricity. In addition, three biomass facilities have been established, with two catering to private farms and one serving a community district heating system.

Figure 4: Wildpoldsried Energy Community

Wildpoldsried's biogas projects have proven to be instrumental in achieving energy stability. Through the anaerobic digestion of agricultural residues, such as manure, the community has unlocked a continuous supply of biogas. This invaluable resource acts as a buffer, compensating for the inherent fluctuations in wind and solar power generation. By incorporating biogas into their energy mix, Wildpoldsried improved the reliability of their energy supply and reduced dependency on conventional energy sources. At the heart of Wildpoldsried's bioenergy achievements lies their innovative district heating system. Powered by biomass, this community-wide initiative supplies 60% of the heating needs for the local area. The system, which has been operational since 2005 and undergoes continuous expansion, exemplifies the community's commitment to providing sustainable heat generation to all its local residents. By utilizing biomass, such as agricultural residues and

[9] For more information, visit: Wildpoldsried.

organic waste from collaboration with local farmers, Wildpoldsried has reduced its reliance on fossil fuels and made significant strides in lowering carbon emissions.

Wildpoldsried's remarkable journey demonstrates the power of starting small and embracing a wide range of renewable energy technologies.

7. RENEWABLE ENERGY TECHNOLOGY COST COMPARISONS

When embarking on an energy generation project, it is crucial to consider the costs associated with different renewable energy sources. Understanding the financial aspects of various options enables informed decision-making and ensures the project's long-term sustainability. To assist in this decision-making process, Table 1 provides an indicative range for the overviews of the Levelized Cost of Electricity (LCOE) for different renewable energy sources, along with other relevant considerations. The payback periods provided below can differ significantly based on location, system size, installation costs, electricity generation amount, and available incentives, which vary across different EU Member States. To learn more about incentives available, please refer to Guidance Document: Obtaining and Managing Finances.

Table 1: Comparative Cost Analysis of Renewable Energy Sources for Energy Generation Projects[10]

Renewable Energy Source	Cost of electricity[11] (€cent/kWh)	Technology Costs (€/kW)	Additional Considerations	Typical payback periods[12]
Wind Power (onshore)	3.94 - 8.29	1,400 – 2,000	Long-term cost efficiency, increased production	6-15 Years
Wind Power (offshore)	7.23 - 12.13	3,000 – 4,000	Higher initial investments	10-20 Years
Solar Power	3.12 - 11.01	530 – 1,600	Abundant solar resources, decreasing system costs, typical solar irradiation conditions	5-12 Years
Biogas	8.45 - 17.26	2,500 – 5,000	Feedstock availability, processing infrastructure	3-10 Years
Biomass (solid)	7.22 - 15.33	3,000 – 5,000	Lower feedstock costs	5-15 Years

Wind power projects, with their declining costs and favourable cost to generate electricity, provide a promising long-term investment. Solar power, with its declining system costs and ample solar resources, is an increasingly attractive choice for residential energy generation and utilisation of space on roofs of buildings. Biomass projects, utilizing biogas or solid biomass, present sustainable alternatives but require careful consideration of substrate availability and associated infrastructure costs. The levelized cost of energy (LCOE) is also significantly influenced by scale, leading to higher costs per kilowatt-hour (kWh) for energy generated from smaller systems.

Ultimately, the choice of renewable energy source for an energy generation project should be based on factors such as **geographical location**, **available resources**, **investment budget**, and **long-term sustainability goals**. With careful

[10] Information cited from: Levelized Cost of Electricity: Renewables Clearly Superior to Conventional Power Plants Due to Rising CO2 Prices - Fraunhofer ISE

[11] Measured by Levelized Cost of Electricity (LCOE).

[12] Disclaimer: Please note that payback periods for renewable energy technologies can vary significantly due to diverse literature sources and numerous factors affecting costs throughout the technology's lifecycle.

planning and consultation with renewable energy experts, your energy community can embark on a successful journey towards clean and affordable energy generation. The factsheets that follow act as a guidance for you to make an initial assessment of what will work best for your locality.

8. OTHER TECHNOLOGIES

This section highlights additional technologies that are well-suited for implementation in rural energy community projects and have the potential to generate energy and revenues while delivering community benefits. These technologies go beyond the major renewable energy generators such as wind, solar, and bioenergy.

Hydropower

Hydropower stands as a reliable and sustainable solution for generating electricity in communities. It harnesses the power of flowing water to generate clean energy, offering numerous benefits for both the environment and local residents. The scale of hydro power projects is an important distinction to consider:

- Large-scale hydro dams are not suitable for rural energy communities due to their significant infrastructure requirements.
- Pumped storage, similar to hydro dams, is also unsuitable for community settings due to its large-scale infrastructure demands.
- On the other hand, run-of-river hydro power, which only requires a river and basic construction, is well-suited for communities.

It is worth noting that hydropower projects, regardless of scale, have longer pre-development, construction, and operational timelines compared to other renewable energy technologies. They also carry higher investment risks, which necessitate specific policy instruments, incentives, and a longer-term policy perspective and vision. Furthermore, the generation of hydropower relies on the natural flows of rivers, and its output has been decreasing due to severe droughts experienced in 2022. Consequently, any feasibility assessment should thoroughly evaluate the selected site, considering potential future impacts of climate change. Public-sector involvement is often critical to develop hydropower projects, due to the high costs and stringent planning requirements. While more than 100 countries worldwide have introduced targets and financial incentives for wind and solar PV, policies targeting new and existing hydropower plans are found in fewer than 30 countries.[13]

Benefits

- A hydro system can operate 24 hours a day, generating substantial amounts of energy that can be self-consumed and sold to the national grid for revenues.
- The renewable and carbon-free electricity generated can be used for both powering and heating homes in the local community.
- May be more cost effective than grid connection in cases where communities are not yet grid connected.

Challenges

- Long, rigorous, and costly planning stage that requires significant investment and time.
- Dependant on availability of water and certain geographic features, like slope and depth, which affect water flow volume and speed.
- Potential for negative environmental effects. The hydro plants can obstruct migratory patterns of wildlife and impact local wildlife through complex balances in the ecosystem.

Heat Pumps

Heat pumps play a crucial role in the context of sustainable heating and cooling systems. They offer an energy-efficient alternative to traditional heating and cooling technologies. By harnessing ambient heat from the air, ground, or water

[13] Information cited from: Hydroelectricity – Analysis - IEA

sources, heat pumps can provide heating, cooling, and hot water for residential, commercial, and industrial settings. Their ability to transfer heat rather than generate it makes them highly efficient, environmentally friendly, and cost-effective solutions for achieving thermal comfort while reducing carbon emissions.

Heat pumps are available in various types:

- **Air-source heat pumps**: These extract heat from the outdoor air to provide heating or cooling.
- **Ground-source heat pumps (Geothermal**): These utilize the stable temperature of the ground for efficient heating or cooling.
- **Water-source heat pumps**: These extract heat from water sources, such as lakes or wells, for heating or cooling purposes.

Each type offers unique advantages and considerations based on factors like heat sources, climate conditions, and installation requirements. Seeking guidance from experts can help determine the most suitable type for your energy community and context.

Benefits

- **Energy efficiency**: Heat pumps are highly energy-efficient, as they transfer heat rather than generate it. They can provide more heat energy than the electrical energy they consume, resulting in lower energy consumption and reduced utility bills.
- **Versatility**: Heat pumps can provide both heating and cooling, making them a versatile solution for year-round comfort. They can reverse their operation, extracting heat from indoors to cool the space during warmer months.
- **Durability and reliability**: Heat pumps are designed to be long-lasting and reliable. With proper maintenance and regular servicing, they can provide efficient heating and cooling for many years, offering peace of mind and avoiding frequent replacements.
- **Cost savings**: While the upfront cost of installing a heat pump may be higher than traditional systems, the long-term savings in energy bills often outweigh the initial investment. The reduced energy consumption translates into cost savings over the system's lifespan.

Challenges

- **Upfront cost:** The initial cost of purchasing and installing a heat pump system can be higher compared to traditional heating and cooling systems. This cost may deter some individuals or businesses from adopting heat pump technology.
- **Retrofitting limitations:** Retrofitting a heat pump system into an existing building can sometimes be challenging, especially if the building's infrastructure is not designed to accommodate the specific requirements of a heat pump system. This can increase installation complexity and costs.

Energy Storage Systems

Energy storage systems that play a vital role in the context of renewable energy generation. These systems are specifically designed to address the intermittency and variability of renewable energy sources, ensuring a reliable and stable energy supply. By storing excess energy during periods of high generation and releasing it during times of high demand or low generation, energy storage systems contribute to the effective integration of renewable energy into the grid and enable enhanced flexibility and efficiency in the overall energy system.

Among the various types of energy storage systems, battery energy storage systems (BESS) play a crucial role in ensuring the continuity of energy supply in renewable energy (RE) projects. These systems utilize rechargeable batteries to store excess electricity generated by renewable sources during periods of low demand or high generation.

There is a distinction between household and neighbourhood batteries as well. Household batteries are specifically designed for residential use and enable the storage of energy generated by solar panels or during off-peak hours. They serve the purpose of providing backup power during outages and promoting energy independence. The investment costs for household batteries vary, ranging from a few thousand to several thousand euros, depending on their capacity and brand. In terms of maintenance, household batteries have relatively low costs and typically require periodic inspections, firmware updates, and potential battery replacements over a lifespan of 10-15 years.

On the other hand, neighbourhood batteries, also known as community energy storage systems, are intended for larger-scale applications, aiming to stabilise the grid, reduce peak demand, and integrate renewable energy sources. These batteries necessitate higher investment costs due to their larger capacity and infrastructure requirements. The costs can range from tens of thousands to millions of euros, depending on the size and complexity of the system. Maintenance expenses for neighbourhood batteries are higher compared to household batteries and include regular inspections, system monitoring, and potential component replacements due to the larger scale and complexity of the system. Neighbourhood batteries generally have a longer lifetime, typically ranging from 15 to 20 years or more, depending on the technology utilised and the maintenance practices implemented. Despite substantial changes to energy storage options in recent years, technologies appear ready to continue developing at this rapid rate. This is likely to drive prices further down while performance improves, making storage an increasingly attractive option for application in energy communities.

Other storage technologies that are less developed but worth keeping an eye on include:

1. **Flywheel** – Kinetic energy is stored in a spinning wheel driven by a motor.
2. **Pump hydro** - An electric pump uses excess power to move water into a reservoir at a higher altitude, which in turn generates energy once released.
3. **Thermal storage** - Excess electricity is used to heat a substance such as salt or stones to be stored in an insulated container. The heat is then released back through a generator and utilized as electricity and heat.

Benefits

- **Smoothing out intermittent renewable energy generation**: Energy storage systems help mitigate the intermittent nature of renewable energy sources by storing excess energy during periods of high generation and releasing it during times of low generation or high demand. This ensures a consistent and reliable energy supply.
- **Enhanced grid stability and reliability**: Energy storage systems provide stability to the grid by regulating frequency and voltage fluctuations. They help balance supply and demand, reducing the risk of power outages and blackouts.
- **Flexibility and peak shaving**: Energy storage systems offer flexibility in managing energy supply and demand. They can store energy during off-peak hours when electricity prices are low and release it during peak hours when prices are high. This allows for cost savings and helps alleviate strain on the grid during peak demand periods.
- **Cost savings**: Energy storage systems can help reduce electricity costs by optimizing energy usage and avoiding high-demand charges. They can also enable energy arbitrage, buying low-cost electricity for storage and selling it back to the grid during peak hours when prices are high.

Challenges

- **Cost:** The upfront cost of energy storage systems can be a significant barrier to widespread adoption. While costs have been decreasing, they may still be prohibitive for certain applications or projects. Additionally, the cost of battery materials and manufacturing processes can affect the overall cost of energy storage systems.
- **Storage Capacity and Duration:** The capacity and duration of energy storage systems may not always align with the required energy demands. Some technologies may have limitations in terms of the amount of energy they can store or the duration for which they can provide power, which can impact their applicability for specific applications.
- **Grid Integration and Interoperability:** Integrating energy storage systems into existing grids can present technical challenges. Interoperability issues, grid compatibility, and system communication protocols need to be addressed to ensure seamless integration and optimal operation.

Hydrogen

Hydrogen is quickly emerging as a promising option for a range of energy applications well suited to energy communities. It is the most abundant element in the universe and can be produced from various sources, including water, natural gas, and renewable energy. In addition, it can be stored and transported like ordinary fuels, or be used in fuel cells and combustion engines to generate power.

One of the biggest advantages of hydrogen is that it produces zero greenhouse gas emissions when used as a fuel, making it a clean alternative to fossil fuels. When hydrogen is combusted or used in a fuel cell, it reacts with oxygen from the air to generate energy, with water being the only by-product.

While hydrogen has been used extensively in some industries for decades, hydrogen-based clean energy technologies are still in the early stages of development and commercialisation. Nonetheless, clean hydrogen and its application for energy storage and fuel is currently enjoying unprecedented political and business momentum, with the number of policies and projects around the world expanding rapidly.

Combined Heat and Power (CHP)

Combined heat and power (CHP) is a highly efficient process that harnesses the heat produced as a by-product of electricity generation. By simultaneously generating heat and power, CHP systems can significantly reduce carbon emissions by up to 30% compared to traditional methods of separate generation using boilers and power stations.

CHP systems make efficient use of the heat that would otherwise go to waste during electricity generation. This recovered heat is then supplied to meet the heating demands of a facility, replacing the need for a separate boiler. The result is a more sustainable and cost-effective solution, as CHP allows heat requirements to be met without the need for additional fuel consumption.

For communities seeking to lower energy costs and improve environmental performance, CHP represents a significant opportunity. Existing users of CHP typically experience around 20% savings on their energy costs.[14] By implementing CHP systems, your community can achieve both financial benefits and contribute to a greener and more sustainable energy future.

District Heating Systems

District heating systems (DHS) provide an efficient and sustainable solution for meeting the heating needs of communities. These systems involve the centralized generation and distribution of heat to multiple buildings and facilities within a district or neighbourhood. One of the key advantages of district heating systems is their ability to capture and utilize waste heat that would otherwise be lost. By tapping into various heat sources, district heating reduces the overall energy consumption and carbon emissions associated with individual building heating systems. District heating systems also offer flexibility and scalability. They can easily accommodate changes in demand by adjusting the heat production at the central plant or adding/subtracting connected buildings from the network.

There are three main types of district heating systems, namely solar thermal, geothermal, and waste heat recovery. Solar thermal district heating systems are very large-scale applications of solar thermal technology. They capture solar radiation and convert it into heat, which is then distributed through the network. Geothermal district heating systems, on the other hand, harness the Earth's natural heat. They extract thermal energy from underground sources like hot water reservoirs or geothermal wells. This renewable heat source is used to produce hot water or steam, which is distributed for various purposes. Additionally, district heating systems can achieve high levels of energy efficiency by utilising waste heat from industrial processes, such as combined heat and power (CHP) plants. Heat produced from these sources is distributed through an insulated network of pipes, delivering hot water or steam to buildings for space heating, water heating, and even industrial processes. To learn more about these types of district heating systems, please refer to the IEA report: District Heating. In Europe, Euroheat & Power in Europe brings together various participants involved in district energy to foster sustainable heating and cooling initiatives. The DHC+ Technology Platform, a component of Euroheat & Power, facilitates additional networking opportunities and coordinates multiple events aimed at promoting district energy and enhancing understanding of technology choices. For example, an

[14] UK Government, Combined heat and power guidance, 2020

opportunity to register for an annual event to learn more about the application of DHS is the International DHC+ Summer School.

9. ADDITIONAL SOURCES

Solar PV

- Solar Energy Technology - IRENA
- Solar Panels for Farms and Agriculture | Solar Power Farm | Geo Green Power
- 5 Ways to Encourage Your Community to Go Solar - ICMA
- Installing Solar Panels in My Community: Permits and Requirements - Mediterrano
- Community Benefits Toolkit - Local Energy Scotland
- Solar PV - Local Energy Scotland
- A comprehensive guide to solar panels - Energy Saving Trust
- Solar PV – Analysis - IEA
- RePowerEU Plan : Joint European action on renewable energy and energy efficiency – Policies - IEA
- Renewable energies: sources, types and benefits | Enel Group

Wind Turbines

- Wind farms: How they work, types, and advantages | Repsol
- Benefits and potential impacts of wind energy | Local Government Association
- So you want to... Build a wind farm? - Farmers Weekly
- Wind Electricity – Analysis - IEA
- Wind - Local Energy Scotland
- Small Community Wind Handbook – Wind Exchange

Biomass and biogas

- What is biogas? | National Grid Group
- An introduction to biogas and biomethane - IEA
- Outlook for biogas and biomethane - IEA
- Biomass - Local Energy Scotland
- Biogas in your local community – European Biogas

Hydropower

- Hydroelectricity – Analysis - IEA
- Community Hydropower - Renewables First
- Use hydroelectricity to power your home - Energy Saving Trust
- Hydropower - Local Energy Scotland
- The changing role of hydropower: Challenges and opportunities - IRENA

Energy Storage

- Energy Storage System - an overview | ScienceDirect Topics
- Energy storage - Fuels & Technologies - IEA
- What is battery storage? | National Grid Group

Heat Pumps

- In-depth guide to heat pumps - Energy Saving Trust
- Heat Pumps – Analysis - IEA
- The Future of Heat Pumps – Analysis - IEA