Renewable energy in EU Rural Areas: production, potential and community engagement

HIGHLIGHTS

- **Rural areas hold more than 80% of the EU's untapped potential** from solar photovoltaics, onshore wind and hydropower, which could generate, respectively, 60 times, four times, and 25% more than today.

- **In 2023, over 70% of the renewable energy** from onshore wind, hydropower and solar photovoltaics **was produced in rural areas.**

- **Onshore wind, hydropower and solar photovoltaics** are the most prominent renewable electricity sources today, **accounting for nearly 1000 TWh/year,** 84% of the total renewable electrical energy produced in the EU in 2023.

- The total EU estimated **electricity generation potential** from onshore wind, hydropower and solar photovoltaics amounts to roughly **12500 TWh/year,** equivalent to more than **5 times the electricity consumed in 2023,** and more than the total energy consumption of the entire EU in the same year.

- **Solar PV energy holds by far the largest potential** among the three sources (88% of potential production), followed by wind and hydropower (11% and 1%, respectively).

- The EU can take advantage of this technical potential with a **sustainable rollout of new installations,** ensuring the preservation of natural and agricultural resources. Considering terrain and climate suitability as well, **around 3.4% of the EU's land could be used** for new solar or onshore wind installations.

- **Citizen-led energy initiatives** are growing in Europe and **can be important drivers in the green transition,** empowering rural communities to tap into their local renewable energy resources.

INTRODUCTION

RENEWABLE ENERGY ON THE RISE

The European Green Deal has made climate change a top priority for the EU. It aims to reduce net greenhouse gas emissions by at least 55% compared to 1990 levels by 2030 and achieving climate neutrality by 2050. Renewable energy (RE) is a pillar of the clean energy transition. The EU's 2030 RE target has been recently increased to at least 42.5% of renewables in the energy mix, nearly doubling the 2022 share of 23% [1,2].

Meeting these decarbonisation goals will require an unprecedented increase in green electricity generation in the coming years. This fast deployment of renewable energy production across the EU territory will transform the energy sector, which is currently responsible for over 75% of the total greenhouse gas emissions in the EU [3]. In 2023, wind, hydropower, and solar photovoltaics (PV) were the main RE electricity generation technologies, accounting respectively for 40%, 30% and 20% of the renewable electricity generated in the EU [4]. To achieve its 2030 targets, the EU needs to roll out 30 GW/year of new wind power, and approximately 45 GWac/year(1) of new PV generation capacity, more than doubling the 2021 capacity of each [5, 6]. As the share of renewable energy increases, system flexibility and energy storage capacity must also significantly grow [7], with some EU studies projecting an expansion from about 60 GW in 2022 to 200 GW by 2030(2).

For the EU's renewables to develop sustainably, a territorial perspective is paramount. In 2021, the European Commission set out a long-term vision for the EU's rural areas (LTVRA) recognizing their significance to Europe's identity and economy [8]. The strategy also aims to support the rural energy transition and to promote stronger, more resilient, connected, and prosperous rural areas. To support a fair and just energy transition in rural areas, new RE installations should be developed in line with EU environmental policy and benefit local communities, where possible.

MAPPING RENEWABLES IN THE EU

This policy brief highlights the key findings of a study [9] that evaluates the current state of renewable energy production from solar PV, onshore wind, and hydro sources(3), as well as their untapped potential (see **Box 1**). It describes the territorial distribution of renewable energy production and potential across the EU at high level of spatial detail, with a special emphasis on the contribution from EU rural areas. Results derive from a collection of spatial and statistical datasets at various spatial resolutions, to quantify both 2023 and future potential energy production from the three renewable sources(4).

SUSTAINABLE DEPLOYMENT OF RENEWABLE ENERGY

The study found that up to 3.4% of the land in the EU is suitable for new wind and solar installations. This assessment takes into account land-use, environmental and technical restrictions and ensures that agri-food systems, landscapes and natural resources are preserved. In this study, agricultural land is not considered suitable for new RE installations, except in areas that have a high risk of abandonment, low productivity and high erosion levels. In the case of hydropower, the installation of new and large dams is excluded due to environmental concerns and regulations, which make new developments less viable. Instead, this assessment considers alternatives to increase hydropower production, such as the modernisation of hydropower plants, adding floating photovoltaics to existing reservoirs and small-hydropower solutions in water utilities. These strategies rely on existing infrastructure, which minimises environmental impact and costs and does not require additional land.

Box 1. Untapped technical potential

Technical potential is the achievable capacity (MW) and energy generation (MWh) of a particular technology considering both physical potential (e.g. solar irradiation, wind speed, water flow), technology energy conversion efficiency and site-specific system performance. It is computed for a certain area, considering topographic, environmental and land-use constraints and provides an upper-bound estimate of the renewable energy potential. The untapped technical potential represents the part of the total technical potential that is not yet exploited.

1 Capacities expressed as AC (alternating current), represent the output the system is designed to deliver to the grid.

2 *https://energy.ec.europa.eu/topics/research-and-technology/energy-storage_en*

3 Other renewable energy sources such as biofuels (e.g. bio-gas, biomass), offshore wind, geothermal or renewable waste are beyond the scope of the analysis.

4 Further details on data sources and resolution can be found in the main report [9].

THE EU RURAL GREEN POWERHOUSE

RENEWABLE ENERGY PRODUCTION

As of early 2023, the EU produced nearly 1 000 TWh/year from three key renewable sources, namely solar photovoltaics, onshore wind and hydropower, making up for 84 % of the renewable electricity produced in the EU in the same year [10][5]. In the EU most of this production occurs in rural areas (72 %), followed by towns and suburbs (22%), and cities (6 %)[6] (**Figure 1**).

Ireland, Cyprus, and Luxembourg stand out with over 90 % contribution coming from rural areas. A few countries produce a lower percentage of renewable electricity from rural areas, ranging from 30-40 %. For Belgium, Bulgaria, and the Netherlands this is partly due to the relatively smaller share of land classified as rural in these countries (47 %, 56 %, and 34 %, respectively). Malta has a limited contribution from rural areas (1 %), which account for only 13 % of the total land. The top five countries in annual electricity production from solar, on-shore wind and hydropower are Germany, Spain, France, Italy and Sweden, with their rural input ranging from 84 % (France) to 56 % (Italy) (**Figure 2**).

Figure 1. Production and potential electricity generation in the EU by degree of urbanisation in 2023.

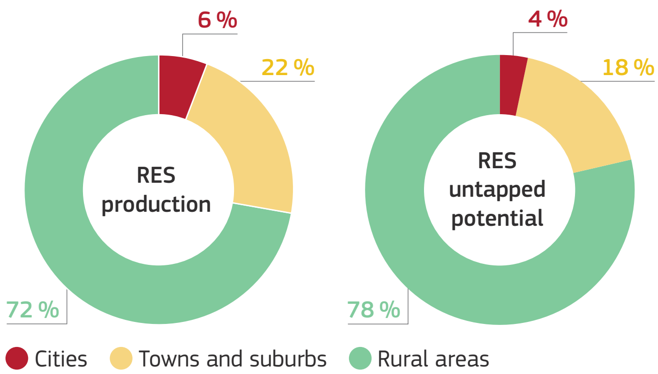
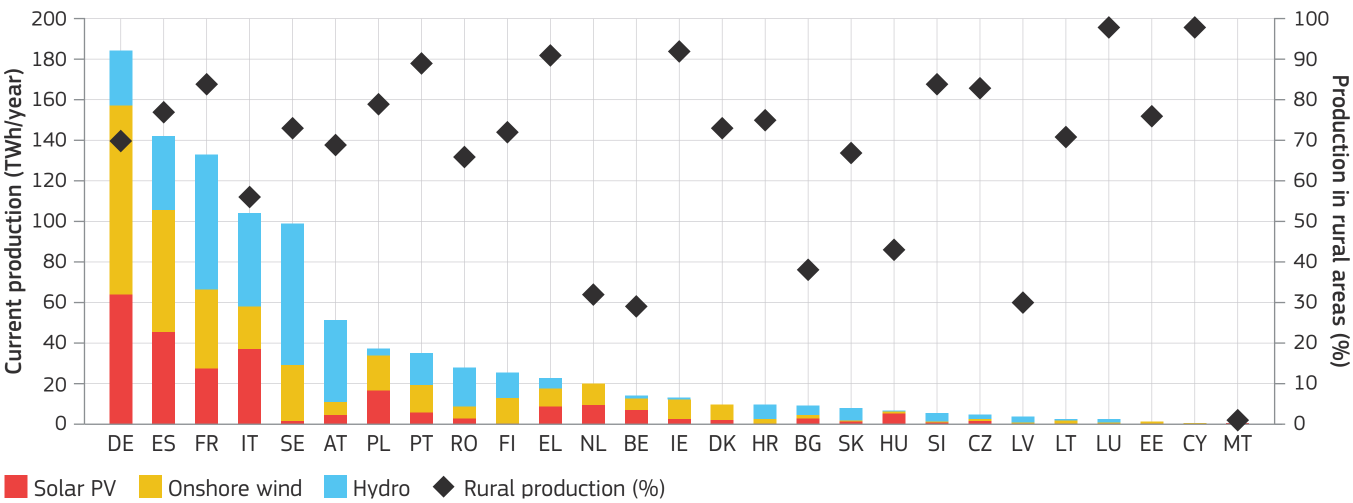


Figure 2. Estimated energy production from solar PV, onshore wind and hydropower and overall rural contribution in the EU, 2023.



EU SUSTAINABLE POTENTIAL

The EU holds an untapped potential for electricity generation of 12 500 TWh/year from new solar PV and onshore wind installations and from enhanced hydropower[7]. This corresponds to more than five times the electricity consumed in the EU in 2023 [11]. Most of this untapped potential originates from solar PV (88 %), followed by onshore wind (11 %) and hydropower (1 %), with the latter including the contribution coming from floating PV on reservoirs (**Table 1**).

Rural areas hold 78 % (9 800 TWh/year) of the EU's combined untapped potential, followed by 18 % in towns

5 These estimates are based on the georeferenced installed capacity registered until mid-2023. They are dependent on the methodology and underlying data and may slightly differ from other assessments and official sources (e.g. Eurostat).

6 For a definition of territorial typologies by degree of urbanisation see *https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Territorial_typologies_manual_-_degree_of_urbanisation*

7 Considering the overlapping of suitable areas for onshore wind and ground-mounted PV, the real untapped potential is slightly lower, but in any case, higher than 11 200 TWh/year.

and suburbs (2 300 TWh/year) and 3.5 % in cities (440 TWh/year) (**Figure 1**). The five MS with the highest combined untapped potential are Spain, Romania, France, Portugal and Italy, together accounting for 67 % of the EU's combined potential, and with the contribution from rural areas ranging from 92 % (France) to 49 % (Italy).

Table 1. Estimated 2023 and potential electricity production in the EU from solar, wind, and hydropower (including floating PV).

EU	SOLAR PV		ONSHORE WIND		HYDRO	
	2023 (est.)	Potential	2023 (est.)	Potential	2023 (est.)	Potential
Production (TWh/year)	250	11 000	350	1 400	375	133

Figure 4 shows the technology with maximum untapped potential, although, from a system perspective, the choice of the best technology to deploy depends on the context and site-specific considerations. The territorial distribution of the combined untapped renewable potential across the EU's municipalities is shown in **Figure 3,** where the annual potential production is depicted per unit area and by degree of urbanisation. Comparing potentials per km² shows which municipalities and regions have the highest possible production relative to their size.

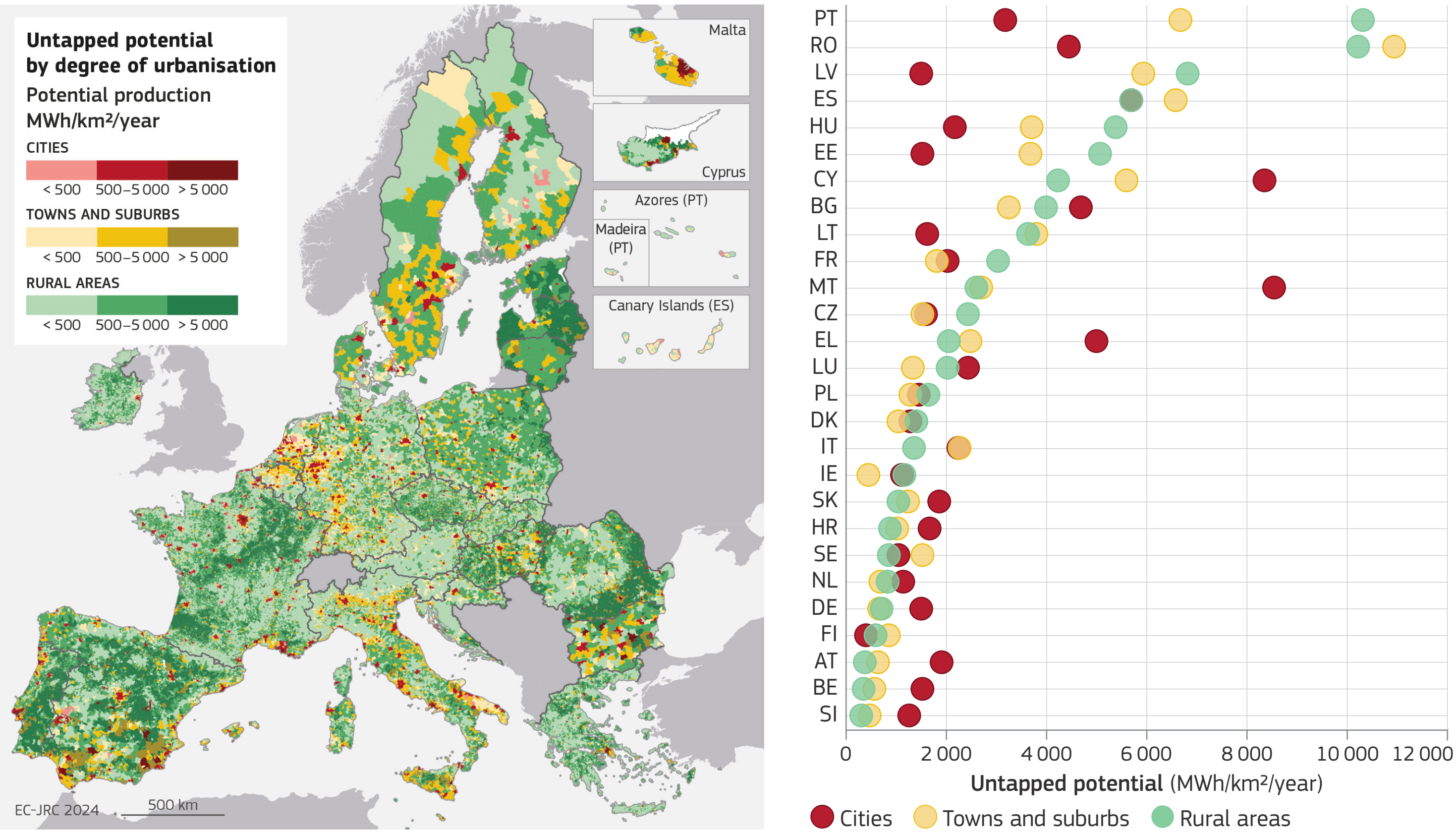
On average, the combined potential per km² of land is highest in the EU's rural areas, where it could reach 3 100 MWh/km² per year, followed by towns and suburbs (2 700 MWh/km²) and cities (2 600 MWh/km²).

The MS with the highest untapped potential per km² are Romania, Portugal, Latvia and Spain, where RE production could reach more than 5 000 MWh/km² per year. Analysing this by degree of urbanisation shows that the highest total untapped potential per km² is found in rural areas of Portugal, as well as in rural areas and towns and suburbs of Romania (**Figure 3**), where it reaches 10 000 MWh/km² per year. In Cyprus, Malta and Greece, cities show the highest potential per km², which is mainly driven by rooftop PV (see the following section).

SOLAR PHOTOVOLTAICS

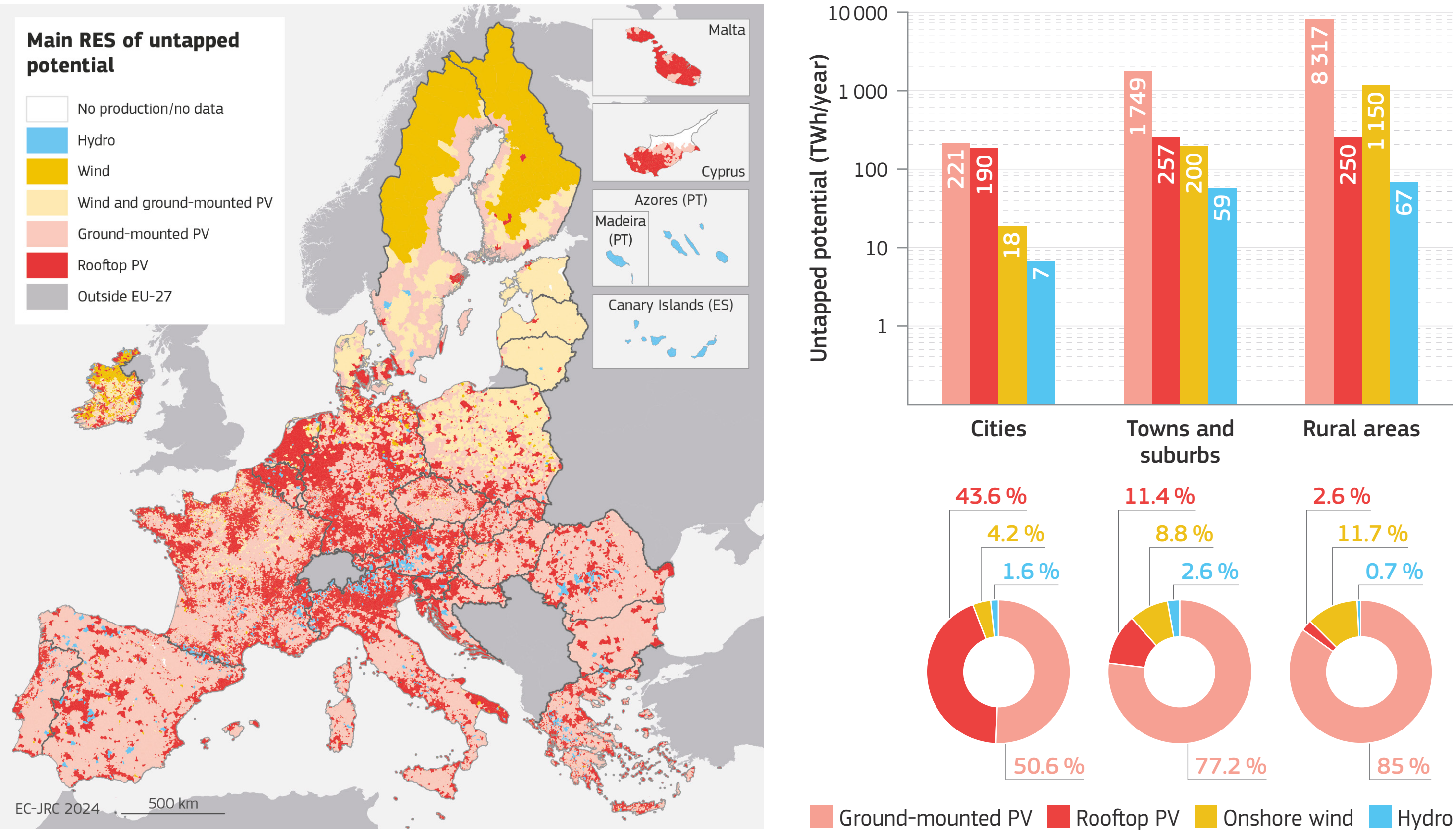
Ground-mounted PV systems are the main source of untapped renewable potential energy generation in the EU. If all the suitable land were used (around 2.2 % of EU land) for new installations[8], the EU could produce up to 10 000 TWh/year more of electricity with ground-mounted PV. This would mainly (80 %) come from rural areas. At country level, Spain and Romania hold, together, 48 % of the EU's ground-mounted PV untapped potential.

Figure 3. Annual untapped potential electricity generation from renewable energy (solar photovoltaics, onshore wind and hydropower combined) in the EU's municipalities (map) and Member States (graph), by degree of urbanisation. Potential energy generation is shown per km², Member states are ranked by rural areas' potential.



8 As stated in the introduction for the purpose of this analysis suitable land is computed enforcing several restrictions on land use, orography, climate, and minimum distances to settlements and infrastructures, the reader is referred to the full study [9] for details.

Figure 4. Main source of untapped renewable energy potential in the EU's municipalities (map), and untapped potential by technology and degree of urbanisation (graph).



Ground-mounted PV systems are typically associated with significant land requirements. However, emerging deployment options such as agri-PV may allow a more multipurpose use of agricultural land [12], making it possible to produce food and energy on the same land.

Rooftop PV solutions are important in highly urbanised areas, as well as in municipalities where suitable land for new installations is scarce. Results suggest that using 26 % of the EU's built-up areas (0.17 % of EU total surface), rooftop PV could produce additional 700 TWh/year of electricity, distributed almost equally between rural areas (36 %), towns and suburbs (37 %) and cities (27 %). Rooftop PV is estimated to be the main source of untapped renewable energy potential in the vast majority (85 %) of the municipalities in Malta, Cyprus, Belgium and the Netherlands (**Figure 4**).

ONSHORE WIND FARMS

Up to 2.8 % of the EU's land could be used to install new onshore wind farms, including turbines and the spacing between them. The assessment of available land excludes all natural and protected areas and most agricultural lands (see [9] for details). Furthermore, as wind farms have a relatively small physical footprint, they can co-exist with other uses.

With the assessed land availability, the EU could generate an additional 1 400 TWh/year of electricity with onshore wind, equivalent to roughly 58 % of the EU's yearly electricity consumption in 2023 [11].

Rural areas hold 85 % of the EU's untapped potential from onshore wind, which places them in a unique position to profit from this technology. Onshore wind can be particularly attractive for municipalities in northern Europe. In the northern regions of Finland, Sweden and Ireland, onshore wind is the leading source of untapped renewable potential (**Figure 4**).

In at least 80 % of the municipalities in Estonia, Latvia and Lithuania, as well as in many municipalities in Denmark and Poland, the untapped potential of onshore wind and that of ground-mounted PV are comparable in terms of yearly energy generation. These areas can benefit from a RE development that combines both onshore wind and photovoltaics.

HYDROPOWER: MODERNISATION AND NOVEL SOLUTIONS

Hydropower is a well-established and advanced technology in the EU, nonetheless the growth of conventional hydropower has been restricted by EU environmental legislation due to potential negative impacts[9]. However, there is still a sustainable and economically viable potential for expansion. This can be achieved through the installation of small turbines in existing hydraulic structures and by upgrading existing plants, including hybridising hydropower with photovoltaics. Fully utilising this potential could increase current EU production by over 130 TWh/year.

Indeed, most of the untapped hydropower potential lies in hybridisation, with the possibility to generate up to 82 TWh/year by covering 10 % of eligible hydropower reservoirs with floating PV systems. The modernisation of existing hydropower plants could also contribute an additional 40-50 TWh/year, while 'hidden' small hydropower opportunities in existing hydraulic structures (namely, water distribution networks, waste-water treatment plants and historical water mills) could generate approximately 5 TWh/year. The modernisation of the existing hydropower fleet, especially for dams, will also allow to improve flexibility, sustainability, and resilience of water infrastructures to climate change.

Approximately 50 % of the EU's total untapped hydropower potential is in rural areas, followed by towns and suburbs (45 %) and cities (5 %). Hydropower is the primary source of RE potential in 1.5 % of EU's municipalities, mainly in mountainous and remote locations with abundant hydrological resources. These areas are mostly located in the Alps, the Pyrenees and the Carpathian Mountains (**Figure 4**). Although hydropower untapped potential is much smaller compared to other renewable energy sources, it has the advantage of relying on existing structures, thus not requiring additional land. Additionally, it is economically and environmentally viable and can produce and store energy in a more flexible manner, making it a valuable complement to intermittent energy sources such as wind and solar. Furthermore, the increasing penetration of wind and solar generation will demand an increase of flexibility and energy storage services. Currently, pumped-storage hydropower provides more than 95 % of the storage capacity in the EU, and most of it is located in rural areas (85 %).

LOCAL VALUE AND CITIZEN ENGAGEMENT

Rural areas will undoubtedly play a vital role in the green transition, given that they host most of the untapped renewable energy potential. There are concerns, however, that increased renewable energy production may not lead to significant local benefits [13]. On the other hand, it is important to recognize the potential for economic growth, income diversification, and job creation that can be fostered through the expansion of renewable energy in rural areas [14]. Moreover, renewable energy expansion in rural areas can serve to decentralize and diversify energy production, simultaneously addressing environmental, climate and security of supply objectives. In this respect, the post-2020 common agricultural policy (CAP) introduced among its objectives of climate action the sustainable production of renewable energy from agriculture and forestry.

However, to effectively link renewable energy with rural development, the implementation of a place-based development strategy is essential [15]. This involves the identification of specific areas that could benefit from a particular renewable energy source. New installations can be linked to the local economy through the tailoring of funding and planning instruments. In addition, inclusive models of governance and citizen engagement can help rural communities benefit more from the renewable energy projects in their territories. Collective ownership of small- or medium-scale energy projects may also represent an attractive opportunity for some rural communities [14].

The number of citizen-led energy projects in Europe is growing. In 2023, the EU had over 4 000 renewable energy associations with 900 000 members [16] while recent Europe-wide inventories have mapped over 10 000 initiatives and 16 000 production units [17]. At the EU level, several initiatives have been put in place to support Energy Communities in rural areas (**Box 2**).

9 In particular, the Water Framework Directive (2000/60/EC), the Floods Directive (2007/60/EC), the EU Nature Legislation (Birds and Habitats Directives) and the EU's biodiversity strategy for 2030.

Box 2. EU support to Energy Communities

The *Clean energy for all Europeans package* adopted in 2019 introduced definitions of Citizen Energy Communities (CEC) and Renewable Energy Communities (REC) in EU legislation. It recognises the key role of local actors in the energy transition process and in promoting wider community benefits from renewable energy production and RE deployment.

Under EU law, energy communities can take any legal form, such as cooperative, small–medium enterprise, or non-profit organization. They are supported through various initiatives which aim to underpin the expansion of grassroot energy projects, by providing tailored technical advice, peer-learning opportunities and policy guidance.

Such initiatives include the Rural Energy Community Advisory Hub[10], which offered specific support to rural actors and provides direct technical assistance to energy communities; the Energy Communities Repository[11] which collects data, documentation and best practices across EU; and the Citizen-Led Renovation[12] service for community-driven renovation projects, which promotes energy efficient and future-proof buildings.

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DISCLAIMER

The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission. The results of this analysis rely on high resolution data from various sources and depend on conservative restrictions for site selection as well as EU-wide assumptions. They consider state of the art technology performances and may differ from similar assessments.

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