Development of Energy Communities in Europe

Hanne Sæle, Andrei Morch,
Dept. of Energy Systems
SINTEF Energy Research
Trondheim, Norway
Hanne.Saele@sintef.no,
Andrei.Morch@sintef.no

Amedeo Buonanno, Martina Caliano, Marialaura Di Somma,
Renewable Energy Sources ENEA
Portici (NA), Italy
amedeo.buonanno@enea.it,
martina.caliano@enea.it,
marialaura.disomma@enea.it

Christina Papadimitriou,
Eindhoven University of Technology (TU/e)
Eindhoven, The Netherlands
c.papadimitriou@tue.nl

***Abstract*—This paper presents a review study of energy communities (ECs) in Europe, and discusses the future development of such communities in Europe – both related to energy technologies, energy carriers, regional conditions (North, Central and South of Europe), emerging regulatory development etc. From the analysis, it emerged that the future ECs in Europe will focus on utilizing local renewable energy sources (sun, wind, run of river, biogas, biomass), for covering all or part of the energy consumption for end-use customers. The ECs can be a sustainable alternative to large power plants based on fossil fuels. This is also linked to the emerging regulatory developments started when European Commission introduced such concepts in the "Clean Energy for all Europeans" package. The main goal of eNeuron H2020 project is to develop innovative tools for the optimal design and operation of ECs, integrating distributed energy resources and multiple energy carriers at different scales.**

***Index Terms*— Clean Energy Package, Energy Communities, Energy transition, Renewable Energy Sources**

I. Introduction

The European Union (EU) set ambitious environmental and energy goals to design a low-carbon energy system, and the EU climate and energy framework establishes targets by 2030 to at least 55% reduction in greenhouse gas emissions (from 1990 levels) [1], 32% share for renewable electricity and 32.5% improvement in energy efficiency [2]. These ambitious targets can be achieved by developing energy systems to support the implementation of three primary goals: protecting the environment, creating affordable and market-oriented energy services, and ensuring security, reliability, and resilience of energy supply.

The EU's climate targets for 2030 supports the objective for climate neutrality by 2050 [3]. The ongoing energy transition brings new opportunities for distributed energy resources (DER) integration and deployment, and for the evolution in the role of final users from passive consumers to active customers who both produce and consume energy. Local energy systems can potentially contribute to the EU energy and climate objectives, by helping reverse energy consumption and emission trends through a bottom-up approach, as also highlighted in the Clean Energy Package for all Europeans where energy communities (ECs) are recognized as an efficient and sustainable way of managing energy at a local community level – with or without a connection to distribution systems [4]. The European Commission has estimated that by 2030 such ECs could own up to 17% of wind power and 21% of solar power in Europe [3].

II. Background

A. eNeuron project

The main goal of the eNeuron H2020 project (Nov 2020 – Oct 2024) is to develop innovative tools for the optimal design and operation of local ECs, integrating DER and multiple energy carriers at different scales. This goal will be achieved by having in mind all the potential benefits achievable for the different actors involved and by promoting the Energy Hub architecture as a conceptual model for controlling and managing multi-carrier and integrated energy systems to optimize their architecture and operation.

In the preliminary phase the eNeuron project has identified and reviewed a selection of active ECs in European countries, to identify their main characteristics as they stand now and examine how local conditions, current policies and practices can influence further development of such communities in Europe.

B. Review process

This paper describes results from a review study performed during 2021. The main objective was to review existing and emerging regulatory developments regarding ECs in Europe - based on the findings of ECs characteristics. In total 76 ECs from 11 European countries have been reviewed, and the main results are presented in the next section.

ECs are identified to be included in the review based on inputs from eNeuron partners, and several open reports summarizing status of ECs in Europe [5][6][7]. Additionally, local websites (where available) have been included as information sources when describing interesting aspects of the ECs. (Relevant links are presented at the end of the paper.)

The eNeuron project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. .957779

978-1-6654-0896-7/22/$31.00 ©2022 IEEE
This is the accepted version of a paper published in IEEE EEM 2022
http://dx.doi.org/10.1109/EEM54602.2022.9921054

III. DEFINITION OF ENERGY COMMUNITIES (ECs)

The term "energy community" (EC) has been conceptually introduced in recent European regulatory acts with at least two alternative descriptions, "citizens energy community (CEC)" and "renewable energy community (REC)".

Two formal definitions of ECs were introduced in two separate Directives included into the "Clean Energy Package" [8]:

- The main framework for the RECs was introduced by and defined in the Renewable Energy Directive (RED II) 2018/2001 [9]
- The concept of CECs was introduced in the Internal Electricity Market Directive (IEM) 2019/944 [10]

The common understanding is that RECs are a legal subset of a broader legal term CECs. A thorough comparative evaluation of REC and CEC can be found in results from the COMPILE project and is not necessary to repeat here [11]. An overview of the definitions of ECs are presented in Table I.

TABLE I. OVERVIEW OF DEFINITIONS OF ENERGY COMMUNITIES (ECs)

Term	Abbreviation	Explanation	Source/Reference
Citizen Energy Community (CEC)			
A legal entity that: a) is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises; b) has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; c) may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders.			“Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU”
Local Energy Community (LEC)			
The term Local Energy Communities (LECs) was initially introduced in the early recasts of the European Directive on Internal Electricity Market (IEM). In the following recasts and approved version of the Directive, this term has been replaced by Citizens Energy Community (CEC) with revised description of it.			Early recasts of the European Directive on Internal Electricity Market (IEM)
Renewable Energy Community (REC)			
A legal entity: a) which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity; b) the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities.			“Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU”

It is worth noticing that these documents do not grant any exclusive rights for ECs to engage in the activities, it rather ensures that they are not excluded from the market and can participate on a level-playing field with other actors.

IV. REVIEW OF ENERGY COMMUNITIES (ECs)

This section summarizes the review results from the review study performed during 2021.

It is important to notice that the analysis is based on the reviewed ECs and available open information about these and is not intended to give a complete description of total number of ECs in Europe.

A. *Country overview*

Within the eNeuron projects, 76 ECs located in 11 different countries have been identified to be included in the review, see Fig. 1.

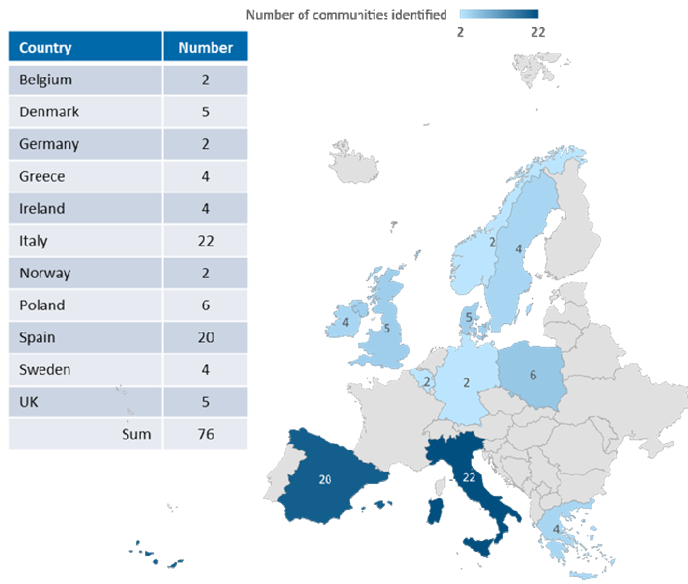

Figure 1. Overview of countries included in the review, and the number of ECs reviewed in each country

The reviewed ECs are divided into the regions North (Denmark, Norway, Sweden, 9 in total), Central (Belgium, Germany, Ireland, Poland, UK, 19 in total) and South (Greece, Italy, Spain, 48 in total).

B. *Energy communities (ECs) characteristics*

1) *Location of energy communities (ECs)*

The different ECs are in different types of geographic areas. Based on the review, there is a limited share of the ECs situated in alpine or island areas, 4% each. The typical is urban (38%) or rural (37%), or a combination of these (17%). Typically, the ECs are connected to the power system at the distribution grid level. When sorting according to regions, ECs are only located in rural (64%) and urban (36%) areas in the north region, but for the central region more than half (53%) of the communities are in combined urban and rural areas, and 21% in rural and 16% in urban areas. In the south region the share of ECs in combined urban and rural areas is 7%, but additionally 48% are located in urban areas and 37% in rural

This is the accepted version of a paper published in IEEE EEM 2022
http://dx.doi.org/10.1109/EEM54602.2022.9921054

areas. The 2% of the communities are located on islands and 7% in alpine areas.

88.2% of the ECs included in the description, are connected to the distribution grid level, while 6.6% to both distribution and transmission grid level, and 2.6% are related to heat production (these communities are focusing on common ownership of a production unit). For 2.6% of communities, the grid level is not specified.

The surveyed ECs define their status in several ways, but the main groups are REC (Renewable Energy Community, 46%) and CEC (Citizens Energy Community, also including LEC, 45%). The most common organizational model of the reviewed ECs is Cooperative (43%) and Partnership (25%).

2) Organizational structure and involved stakeholders

It should be possible for Member States to provide that ECs take any form of entity, for example that of an association, a cooperative, a partnership, a non-profit organization or a small or medium-sized enterprise, provided that the entity is entitled to exercise rights and be subject to obligations in its own name [10]. The legal organizational model is specified for each ECs in the review, as presented in Fig. 2. The largest part is cooperatives, representing 43% of the ECs.

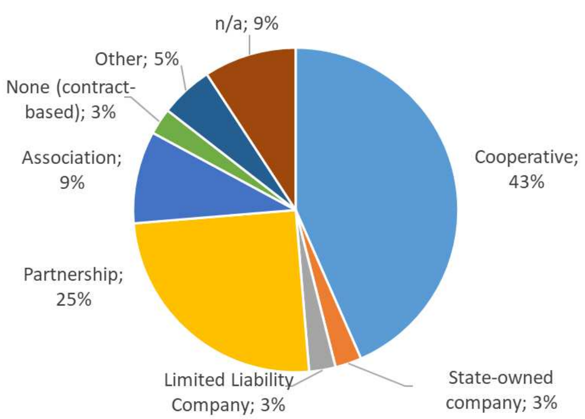

Figure 2. Organizational model of reviewed ECs

An overview of the organizational models in a regional context is presented in Table II. For all the regions "Cooperative" is the most common model chosen (North: 36.4%; Central: 42.1%; South: 45.7%). For the central region also "Partnership" is a common organizational model with a share of 42.1%. "Partnership" is the second most common organizational model, with 25.0% in total (North: 9.1%; Central: 42.1%; South: 21.7%).

TABLE II. ORGANIZATIONAL MODELS IN A REGIONAL PERSPECTIVE

Organizational model	North	Central	South
Cooperative	36.4 %	42.1 %	45.7 %
State-owned company	0.0 %	5.3 %	2.2 %
Limited Liability Company	9.1 %	5.3 %	0.0 %
Partnership	9.1 %	42.1 %	21.7 %
Association	18.2 %	0.0 %	10.9 %
None (contract-based)	0.0 %	5.3 %	2.2 %
Other (pilot projects)	27.3 %	0.0 %	2.2 %
n/a	0.0 %	0.0 %	15.2 %

The typical ECs are involving citizens, predominantly in a cooperative. The availability for new energy technologies (for example PV-panel, battery, windmill) enables the citizens to be a part of the power system. In areas with weak grid/long distances with overhead lines, where there can be challenging to maintain the security of supply from the main power system, local initiatives from the citizens and/or the municipality can be a good alternative. Such initiatives are often referred to as "energy islands".

3) Motivation for establishment

The motivations for establishment of ECs differs. In the survey, nine different motivations were considered, and several motivations can be specified for each community. An overview is presented in Fig. 3.

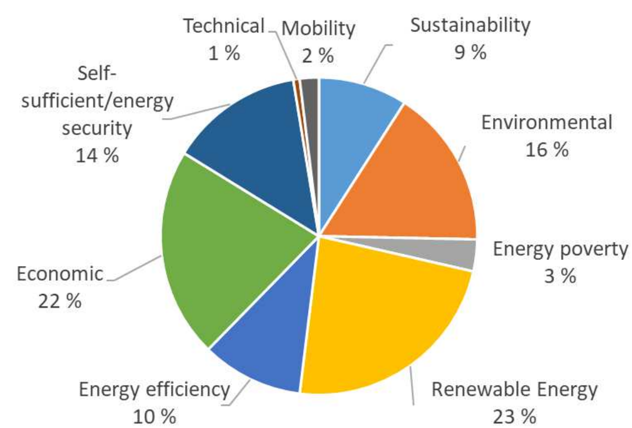

Figure 3. Motivations for establishment of ECs

Use of local sources is important for establishment of ECs, and also for establishing a sustainable solution for the involved citizens. For the ECs included in the review, 23% specifies that use of renewable energy is the main motivation for establishment of the EC, for all the studied regions (North, Central and South). Other important reasons are energy efficiency and flexible resources that contribute to improved utilization of electricity grid (cost-efficient operation and reduced need for grid investments), but also the possibility for improved hosting capacity to increase the number of generation units based on renewable energy sources (RES) connected to the power grid.

The motivations in a regional perspective are presented in Table III. For the north region, only five different motivations are specified: the main focus is on renewable energy (46.7%), followed by environmental (20.0%). Energy efficiency and sustainability both have a share of 13.3%. For the central region, nine different motivations are presented, where renewable energy is the largest (19.2%), followed by economic motivation (17.3%). In the south, eight different motivations are specified, where the most important is economical (26.4%) and renewable energy (21.8%).

This is the accepted version of a paper published in IEEE EEM 2022
http://dx.doi.org/10.1109/EEM54602.2022.9921054

TABLE III. MOTIVATIONS FOR ESTABLISHMENT IN A REGIONAL PERSPECTIVE

Motivation	North	Central	South
Sustainability	13.3 %	15.4 %	4.6 %
Environmental	20.0 %	15.4 %	16.1 %
Energy poverty	0.0 %	3.8 %	3.4 %
Renewable energy	46.7 %	19.2 %	21.8 %
Energy efficiency	13.3 %	11.5 %	9.2 %
Economic	6.7 %	17.3 %	26.4 %
Self-sufficient/energy security	0.0 %	13.5 %	16.1 %
Technical	0.0 %	1.9 %	0.0 %
Mobility	0.0 %	1.9 %	2.3 %

The motivation to be self-sufficient/energy security and the motivation related to energy poverty are not the largest shares, but these motivations are only specified for the central and south region.

4) Installed technology

The energy technologies installed in the reviewed ECs are presented in Fig. 4. The most common energy technology installed is PV, with a share of 47%. Other energy technologies installed are storage (13%), wind (12%), CHP/Bio (12%), EV/Charging station (8%), hydropower (4%) and heat pump (4%).

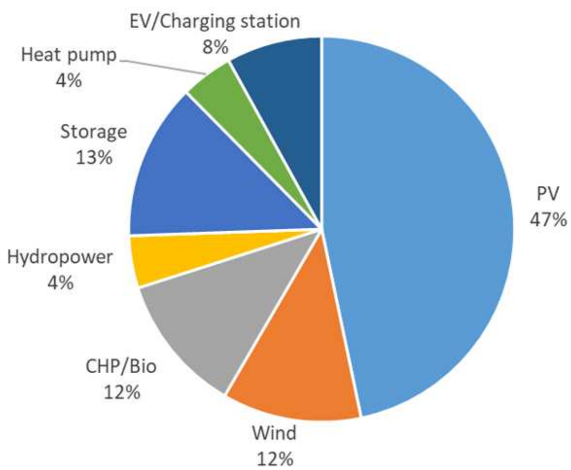

Figure 4. Energy technologies installed in reviewed ECs

In a regional perspective, PV is the most common energy technology (North: 34.8%; Central: 31.4%; South: 63.5%). For the north region, also storage (21.7%), EV/charging station (17.4%) and heat pump (13.0%) are often used. In the central region, wind (21.6%) and CHP/Bio (21.6%) are common technologies. In the south region, storage is the most common energy technology (11.1%) after PV.

Electricity is the main energy carrier in most of the ECs included in the review (69%). Other energy carriers such as biomass (16%), thermal (12%), hydrogen (1%), gas (1%) and diesel fuel (1%) are also included in some communities, but always in addition to electricity.

5) Potential benefits created by the community

The study considers a set of potential benefits, which are provided from the communities to the whole society and increase the overall social welfare. The potential benefits from reviewed ECs are also included and can be grouped according to the topics: Sustainability/ Environmental, Energy technologies, Power system, Economical, Society (local), Community, Social (energy consumption), and Social (other).

Potential benefits related to *sustainability/ environmental* are the possibilities for sustainable energy supply, supporting UN's 17 sustainable development goal. Additional benefits are the possibility to support climate change mitigation, improvement of the natural environment and contribute to a more sustainable way of mobility (incl. less pollution from transportation). ECs will also contribute to reducing CO2 emissions, supporting initiatives which have the most significant carbon savings impact and deployment of green solution contributing to reduced greenhouse gasses (GHG) emissions.

ECs will also contribute to increase the use and acceptance of new *energy technologies*, and of local energy resources for energy production and storage, boosting the energy produced by RES and sharing RES with neighbors - without intermediary parties.

For the *power system* ECs will contribute to increase share of RES in local grid and increase utilization of different types of flexible resources, as a cost-efficient alternative to grid investments. A potential benefit is also the reduction of connection costs for RES, and to enable greater renewable generation (and therefore lower generation costs), both through the connection of additional capacity and by reducing the need to curtail existing generation capacity. A potential benefit related to increased deployment of ECs with increased amount of RES connected is a more efficient and reliable management of electric grid, improve the quality of service and the hosting capacity.

A qualitative evaluation of potential *economic* benefits is related to the members of the community, with lower electricity bills due to cost reduction for consumers and income from selling electricity. Some of the reviewed communities also estimated economic benefits from visitors who come to learn about the project (knowledge sharing) and the possibility for creating opportunities for local and responsible financial investment.

For the *local society* potential benefits are related to promoting ECs, democratize energy production, develop local employment, with more environmentally friendly solution for the future, improve economy and competitiveness of the local economy. Additional benefits are related to use of local energy resources for energy production, cooperation of local stakeholders and activating the local community, and use of local human and technical resources. Further, ECs can represent a development impulse for business, creating jobs in the construction and maintenance of production sources and the necessary infrastructure, increase the tourist attractiveness of the region, contribute to economic savings both for the city and their neighbors and provide training, volunteering, and employment opportunities for local people.

Potential benefits for the *community* can be related to optimize the economic benefits for the community members and promoting the idea of a prosumer society.

This is the accepted version of a paper published in IEEE EEM 2022
http://dx.doi.org/10.1109/EEM54602.2022.9921054

There are also estimated some potential *social* benefits related to *energy consumption*, such as the possibility to maximize the instantaneous self-consumption of energy, increase energy awareness, engage knowledge and expertise of local community, reduce energy demand, lower electricity bills for the members of the community, eradicating energy poverty with the possibility to have access to local generation of electricity, improving the safety and reliability of energy supply to end-users, guaranteeing economic savings (for communities currently destined for families in energy poverty and later for all participating neighbors), raising awareness about energy efficiency, savings and tackling fuel poverty, encourage behavioral change relating to sustainability and helping make host buildings more sustainable.

Other social benefits can be related to possibility to promote agricultural enterprise and food territory products, development of ecological energy sources and pose the basis for new added value services.

V. Discussion and conclusion

To summarize, the future ECs in Europe are expected to focus on utilizing local renewable energy sources (sun, wind, run of river, biogas, biomass), for covering all or part of the energy consumption for end-use customers to contribute to the energy transition as envisioned by EU. Being responsible for part of the energy generation, ECs can both make the customers more aware of their use of energy, but also be a solution to reduce the amount of energy poverty (assuming sufficient funding arrangements from private and/or public stakeholders). There are several existing organizational models for ECs in Europe, in which citizens are highly involved in decision-making, or where there is an emphasis on local benefits such as energy access, job creation, community regeneration and education. They can be a sustainable alternative to the large power plants based on fossil fuels as well. This is also linked to the emerging regulatory developments started when European Comission introduced concepts such as RECs and CECs in the "Clean Energy for all Europeans" package, and further described in both directives RED II and IEM. Benefits arising from ECs can be multi-fold and lie in a different spectrum of social, economic, and technical aspects. What is important is the efficient interpolation of the EU regulation in the national frameworks so that the ECs serve at their full potential related to their primary objective of having citizens at the center and contribute in the energy transition vision.

Acknowledgment

The eNeuron project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 957779

References

[1] European Commission, "2030 Climate Target plan", https://ec.europa.eu/

[2] European Commission, "2030 climate & energy framework", https://ec.europa.eu/

[3] Energy Transition, "Energy Communities: The hidden gems of the EU energy transition"; https://energytransition.org/

[4] European Commission, "Clean energy for all European package", https://energy.ec.europa.eu/

[5] JRC Science for Policy Report, "Energy communities: an overview of energy and social innovation," https://publications.jrc.ec.europa.eu/

[6] Bridge Horizon 2020, "Energy communities in the EU. Task Force Energy Communities," https://www.h2020-bridge.eu/

[7] NVE-report, "Descriptive study of Local Energy Communities," http://publikasjoner.nve.no/

[8] The European Commission, "Clean energy for all Europeans package," https://ec.europa.eu/

[9] The European Commission, "Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources,," https://eur-lex.europa.eu/legal-content/

[10] The European Commission, "The European Commission, "Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU," https://eur-lex.europa.eu/legal-content/

[11] J. Roberts, D. Frieden and S. d'Herbemont, "Energy Community Definitions," May 2019. https://www.compile-project.eu/

Relevant links to websites for ECs

energent.be, www.beauvent.be, www.middelgrunden.dk, eboconsult.dk, bbf-veo.dk, www.solarmarstal.dk, the-energy-collective-project.com, enercommunities.eu, www.comunirinnovabili.it, blue-fifty.com, klasterzywiec.pl, www.score-h2020.eu, klastermichalowo.pl, www.enercoop.es, gasteizberri.com, halabedi.eus, comunidadesenergeticas.org, lacorrientecoop.es, www.ree.es, ecodes.org, lapalmarenovable.es, www.cooperase.org, solmatch.repsolluzygas.com/, www.somenergia.coop/, www.sommobilitat.coop, www.hsb.se/sydost/brf/lyckansberg/miljo/solceller/, www.lrf.se/, www.solbyn.org, brixtonenergy.co.uk/, www.edinburghsolar.coop/, www.energy4all.co.uk, isleofeigg.org/eigg-electric/

This is the accepted version of a paper published in IEEE EEM 2022
http://dx.doi.org/10.1109/EEM54602.2022.9921054