School of Industrial and Information Engineering
M.Sc. Electrical Engineering

Renewable Energy Communities

Regulatory Framework, Benefits and Challenges

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1 Introduction

In the last decades, energy from Renewable Energy Sources has become more and more relevant in the European energy scenario in order to contrast the effects of Climate Change since they provide clean and affordable energy. In fact, several proposals have been carried out by the European Union in order to facilitate the integration of Renewable Energy Sources in the electric power system: over the time, the level of ambition regarding the share of energy from Renewable Energy Sources has gradually increased. Moreover, in recent years, concerns of citizens due to social, economical and environmental reasons led to more involved consumers into energy issues.
According to a study conducted in collaboration among the departments of Electrical and Computer Engineering, Psychology and Social Sciences of the University of Puerto Rico [1], three main aspects are linked with the progressive increasing participation of consumers in the power sector:

1. Consumer's Choice: Traditional users had in the past just a passive role in the electricity system, but nowadays it has changed since they gained a new active role. Several proposal have been carried out in order to improve the consumers awareness about energy issues, such as Time of Use tariffs, efficiency schemes and self-consumption from Renewable Energy Sources. Nevertheless, the individual participation of single user is not enough to reach well-spread results, meaning that collective actions should play a key role.

2. Local Control: The introduction of instruments to allow the citizen participation in energy issues can help reducing the gap between government decisions and communities needs since community members can directly intervene to better address their own energy and environmental needs.

3. Access to the Process: Existing institutions should facilitate the integration of citizen participation into existing processes.

Therefore, it is not surprising that one of the last European proposals, introduced with the EU Directive 2018/2011 in the *Clean Energy for All European* Package, was related to collective self-consumption in forms of Renewable Energy Communities, also in compliance with the sustainable development goals number 7 *Clean and Affordable Energy* and number 11 *Sustainable Cities and Communities* set by the United Nations in the Agenda 2030 [2]. In the next sections, in order to understand what Renewable Energy Communities are and why we should implement them, the European regulatory framework and its transposition into the Italian scenario are presented. Later on, their major benefits are introduced, in particular focusing on their economic and social ones. In the end, the main related challenges are discussed.

2 EU Regulatory Framework

Renewable Energy Communities are defined as legal entities made by natural person, small-medium size entrepreneurs and local authorities that utilize, store, share and sell self-produced electricity from Renewable Energy Sources among the members of the community that is placed in proximity of the community plants. In fact, the main goal of these communities is not gaining money, but it is providing environmental and social benefits to the members.
They were introduced with the EU Directive 2018/2011 [3], in the *Clean Energy for All European* Package, that promotes the usage of energy from Renewable Energy Sources at European level.

(a) Any chosen legal form is accepted, but it is necessary to consider that it may lead to both rights and obligations.

(b) The community must not be the primary activity for entrepreneurs that take part in it.

(c) Community members maintain their rights and duties as consumers and they are free lo leave when they desire so.

(d) Renewable Energy Communities can access to all electricity markets, even the ancillary services one, both individually or through aggregation.

(e) Energy is shared among members by using the public distribution grid, so community members are charged with network charges.

(f) Renewable Energy Communities are directly incentivised by means of support schemes.

The EU Directive has the scope to give binding guidelines to Member States, but the specific implementation is left to the individual countries, meaning that they need to transpose the general concepts highlighted in the Directive into more peculiar instructions at national level by means of national laws.

3 Italian Transposition of EU Directive

The transposition of the EU Directive into the Italian regulatory framework is a long and articulated journey, made of several laws, decrees and documents, that started in 2020 with the publishing of the Art. 41 bis in the law 2020/8. Later on, the Italian regulator ARERA published its own consultation document, while the regulation of the incentives for Renewable Energy Communities was defined by the Ministry of Economic Development with its ministerial decreed published in September 2020. The final transposition of the EU Directive was reached in 2021 by means of the legislative decree 199/21. Moreover, investments for Renewable Energy Communities were also introduced in the National Resilience and Recover Plan launched by the Italian Government in 2021. Lastly, the most updated consultation document was recently published by the Italian regulator ARERA at end of December 2022.

3.1 Law 2020/8

The first partial transposition of the EU Directive 2018/2011 into the Italian regulatory framework happened in 2020 with the Article 41 bis in the law 2020/8 [4] which stated, among others, the possibility for consumers to start a Renewable Energy Community.

(a) The maximum installed capacity for plants that are part of a Renewable Energy Community is limited to 200 kW.

(b) Community members share electricity by means of the public distribution network, so they need to be located under the same LV network. This implies that community members are charged with system charges and discounted network charges for the shared energy.

(c) The hourly shared electricity is defined as the minimum between the amount of injected self-generated electricity and the amount of withdrawal electricity of the whole community.

(d) The economic settlement among community members is regulated by means of a private contract, in which a uniquely delegated subject is identified to manage the sharing of energy. It can also manage the payments between the sellers and the GSE.

(e) Renewable Energy Communities can access to the incentives which are not compatible with the on-spot trading mechanism. The incentives must be defined by the Ministry of Economic Development to promote self-consumption, both instantly and through storage systems. They are provided by the GSE for a limited amount of time in order to ensure the bankability of the investment.

(f) The Italian regulator ARERA must take actions to promote the cooperation of DSOs and the TSO, in particular regarding the methods to make available the measurements of shared electricity. Moreover, it must identify the network charges components that are not directly applicable to the shared electricity.

3.2 ARERA Consultation Document 318/2020/R/eel

In order to comply with the decisions of the previous law, the Italian regulator ARERA published in 2020 a consultation document [5] regarding the regulation of shared electricity for renewable self-consumers who act collectively in buildings or in Renewable Energy Communities.

(a) Subjects that would like to set up a Renewable Energy Community should submit an application to the GSE. If the application has a positive result, the GSE stipulates a contract with the manager of the configuration. The contract has a duration equal to the incentive period defined by the Ministry of Economic Development and it is updated in case of changes that affect the calculation of the contributions, such as the entry and the exit of community members.

(b) Shared electricity is reimbursed of some network charges components with a contribution that is defined starting from the computation of the monthly shared electricity E_{AC} [kWh/month], which is equal to the sum of the hourly shared electricity for the month. Then, the contribution on the shared electricity C_{AC} [€] is computed monthly by the GSE as the product between the shared electricity E_{AC} and a flat-rate tariff CU_{Af} [c€/kWh].

$$C_{AC} = CU_{Af,m} \times E_{AC}$$

(c) Shared electricity is further encouraged by adding a coefficient of network losses avoided c_{PR} that represents the positive effect of the shared electricity on losses in the distribution and transmission network. In particular, it is equal to 2.6% in the case of shared electricity from plants connected to the LV distribution network.

3.3 Ministerial Decree 16/09/2020

The ministerial decree published by the Ministry of Economic Development in 2020 [6] defines the level of the incentives that can be granted to Renewable Energy Communities.

(a) The incentive is entitled to Renewable Energy Source plants that takes part in configurations of collective self-consumption or Renewable Energy Communities.

(b) In Renewable Energy Communities, the incentive is applied on the shared electricity for a period of 20 years in form of a premium tariff equal to 110 €/MWh.

(c) The incentive is compatible with the 110% deduction, but not with the on-spot trading mechanism.

(d) Subjects that entered in operation after the beginning of March 2020 and benefit from the on-spot trading mechanism can abandon it in order to insert the same plant in a collective self-consumption or a Renewable Energy Community configuration in order to access the incentives of this decree.

3.4 Legislative Decree 199/21

The Article 8 of the legislative decree 199/21 [7], published in 2021, defines the access procedure and the rules for granting the incentives also in Renewable Energy Communities.

(a) The incentives in Renewable Energy Communities is distributed as a tariff in form of single adjustment.

(b) The access to the incentive is granted by means of a tendering procedure and the incentives are guaranteed up to the achievement of a predefined power, defined every five years.

3.5 National Resilience and Recovery Plan

In the National Resilience and Recovery Plan [8], published in 2021, further investments are planned to support Renewable Energy Communities in order to extend the experimentation started with the previous transpositions. In particular, 2.20 million Euro are reserved for investments in Renewable Energy Communities, in particular for those municipalities with less than 5000 inhabitants, which are often at risk of depopulation.

3.6 ARERA Consultation Document 727/2022/R/eel

The most updated consultation document regarding the regulation of self-consumption electricity was published at the end of December 2022 by the Italian regulator ARERA [9]. In particular, it introduces some innovative aspects regarding the implementation of collective self-consumption schemes and Renewable Energy Communities.

(a) Members of Renewable Energy Communities have to be connected in the same market area, but the computation of the shared electricity is made by the GSE by considering the area underlying the same primary substation.

(b) The DSO is responsible for defining and publishing on its website a map of the underlying areas for every primary substation.

(c) The duration of the contract established between the manager of the configuration and the GSE has a duration that is defined by the GSE itself, but it has to take into account the duration of the incentive period defined by the Ministry of Economic Development.

4 Renewable Energy Communities in Italy

According to the RSE database [10] about the number of Renewable Energy Communities, at the moment there are about 25 communities that operate actively on the Italian territory, in compliance with the law 2020/08, and they are shown in Figure 1. As it is possible to observe, they are not equally distributed among all the Italian regions since some of them present a high concentration in the number of communities, such as the region of Sicily, while others present just one or not community at all. Nevertheless, this is coherent with the spacial distribution of Renewable Energy Sources in Italy that are predominantly concentrated in the South of the country.

Figure 1: Location of actual Renewable Energy Communities in Italy

5 Benefits and Challenges

5.1 Environmental, Economic and Social Benefits

As stated in the EU Directive 2018/2011, Renewable Energy Communities have the primary goal to provide environmental, economic and social benefits to their community members, rather than merely financial profits.
One of their main advantages is surely related to the environmental aspect of these communities since they are explicitly based on Renewable Energy Resources. Moreover, Renewable Energy Communities bring with them also several economic benefits. In fact, prosumers in the community can reduce the energy component of their electricity bill by using self-generated electricity, instead of withdrawing it from the public grid. Moreover, their costs can be further reduced thanks to the incentives granted by the Government on shared electricity and to the injection of the remaining electricity into the public grid. Nevertheless, community members that are not owners of their own plant can still take advantage of electricity generated by other members of the community, leading to a considerable reduction of their electricity bills as well. In fact, considering all the available

incentives, electricity in Renewable Energy Communities is valorised by means of several economic components.

- The contribution C_{AC}, defined by the Italian regulator ARERA, on the shared electricity for the reimbursement of some network charges components, according to a cost-reflective usage of the network.
- The incentive defined by the Ministry of Economic Development equal to 110 €/MWh on the shared electricity.
- The remuneration at the Zonal Price of the energy injected into the grid.

This particular aspect must be taken into account as a powerful tool to contrast energy poverty since it can help protecting the more vulnerable consumers. In fact, Renewable Energy Communities have the theoretical potential to actually address several issues related to energy justice [11], in particular in its procedural, distributional and recognitional tenets.

- Procedural Justice: It refers to the implementation of procedures that allow a non-discriminatory and inclusive participation. In order to deploy a fair environment, it is necessary to consider that barriers to enter the community can also be related to the business model of the community itself, such as its primary goal. This implies that the decisions taken between community members could be biased, preventing the involvement of social groups that are not perceived to share the same values. On the other hand, the behaviour of vulnerable consumers themselves can represent a barrier to enter because they often lack of social and economic capital, such as information about the possibility to become a member of the community or the lack of financial resources to invest.
- Distributional Justice: It focuses on where energy injustices emerge. Renewable Energy Communities can contribute to it by allowing groups of users to access services that usually they do not benefit from, for example by implementing activities specifically dedicated to vulnerable consumers or by proving lower tariffs to them.
- Recognitional Justice: It investigates in which sections of society needs are ignored or misrepresented by accommodating necessity of underrepresented social groups. The active participation of vulnerable consumers in the decision-making is essential for contributing to this kind of justice. In fact, Renewable Energy Communities rely on volunteers that might live in a reality that is considerably different from those of vulnerable groups, leading to difficulty when it comes to understand their real needs.

But Renewable Energy Communities are not just a collective self-consumption scheme: they actually improve the quality of the community by providing also other major social benefits [1]. For example, the sense of belonging to the community is reinforced and this plays a key role in small realities where community members can share resources and help when it is necessary. Moreover, Renewable Energy Communities allow the empowerment of the communities themselves because, by encouraging the participation of the citizens to energy issues, it is possible to promote innovative ideas to better address the needs of the community.

5.2 Main Challenges

Some elements that could obstacle the deployment of Renewable Energy Communities are related to the elements listed below.

1. Non-Existing Sense of Community: It could prevent the formation of the community from the beginning since people are not interested in creating one.

2. Agreement on Level of Shared Energy: This aspect could be solved by implementing energy schemes in order to achieve an efficient energy exchange among community members. Either self-consumption or peer-to-peer exchange can be optimized.

3. Profit Sharing: The time needed to recover from the investment or the quantification of savings in the electricity bill could represent a source of disagreement among community members.

4. Lack of Specialized Knowledge: At least in this historical moment, it is necessary to have additional knowledge in order to effectively set up and participate in the community since normal people may not be informed about the opportunity and how to access it.

5. Underlying Areas of Primary Substations: The belonging to the same primary substation is an essential characteristic in order to access the opportunity to set up a Renewable Energy Community. The issue is mainly related to the lack of maps, containing these information, available to citizens.

In the following sections, three of these main challenges are deeply investigated: firstly, the role of the DSOs to deploy a map of underlying area of every primary substation is considered; then, examples of energy efficiency schemes are proposed as possible solutions in order to efficiently exchange self-produced electricity among community members; lastly, examples of profit sharing mechanisms are highlighted.

5.2.1 Role of DSOs

The Article 10 in the consultation document 727/2022, published by the Italian regulator ARERA [9], addresses specifically the issue related to the lack of information regarding the underlying areas of every primary substation. The document defines the rules and the future path to follow in order to deploy a common strategy among all DSOs.

(a) DSOs should deploy solutions, starting from their actual network configuration, in order to identify the underlying areas of every primary substation, also taking into account the future network deployments that are known at the time of identification.

(b) All DSOs should coordinate among themselves in order to deploy similar solutions.

(c) The map of underlying areas of every primary substation must be published in the DSO website before the end of February 2023. The map is opened for consultation of interested parties, that can forward their observations to the DSO, until the end of May 2023 after which the map should be updated with appropriated changes.

(d) Starting from the beginning of October 2023, the map is updated at least every two years by the DSO, in order to consider the evolution of the electric network, and it must be sent to the GSE in such a way that it is able to publish it on its IT portal.

5.2.2 Efficient Energy Exchange

One of the possible ways to set up an efficient scheme to exchange self-produced electricity is based on a blockchain algorithm, as shown in the study carried out by Stefan M. et al. [12]: in case of Renewable Energy Communities, every community member is equipped with additional hardware and software components and it is part of a blockchain system. In particular, every customer can choose to focus on the optimization of either self-consumption or peer-to-peer energy trading with the community members. Both configurations work in similar ways, even if they differ for the order of some steps in the algorithm.

(a) Self-Consumption Optimization

(b) Peer-to-Peer Trading Optimization

Figure 2: Blockchain strategies for efficient energy exchange

- Self-Consumption Optimization: The surplus of the self-generated electricity from a user is firstly fed into a community battery for later re-use of the user itself (S_1); only when the battery is completely charged, it is sold firstly to the other members of the community (S_2) and lastly to retailers on the public network (S_3). Moreover, the user's consumption is firstly supplied with electricity previously stored in the community battery (D_1); only if the battery is empty, electricity generated by other community members is used (D_2), while the withdrawing of electricity from the public grid (D_3) represents the last option that is chosen only if all the previous ones are not available.

- Peer-to-Peer Trading Optimization: It works in a similar way but, in this case, the trading with the other community members is preferred, meaning that the electricity surplus is firstly traded with other members (S_1) and it is stored in the community battery (S_2) only if no member needs it. Moreover, the user's consumption is firstly supplied with electricity generated by other community members (D_1) and the stored energy in the community battery (D_2) is used only if no member has a surplus of production. As in the previous configuration, the public network represents the last option both in case of electricity surplus (S_3) and consumption (D_3).

This approach is surely easy to manage, but its main disadvantage is related to the fact that it does not manage the division among community members of the energy that is shared. In order to overcome this problem, it is possible to deploy an optimization model, as presented in the analysis carried out by Giordano A. et al. [13], in order to take into account the global picture of the community and not just the needs of single users. In this model, the objective function is the minimization of the total energy costs, computed as the sum of costs (positive) and revenues (negative), sustained by the community members.

$$min \sum_{u \in U} \sum_{h \in H} (c_h \times E_{imp_{h,u}} - p_h \times E_{exp_{h,u}} + PUN_h \times E_{impG_{h,u}} - P_{zh} \times E_{expG_{h,u}})$$

In particular: $E_{imp_{h,u}}$ and $E_{exp_{h,u}}$ represent the electrical energy imported from and exported to the community at hour h by user u; $E_{impG_{h,u}}$ and $E_{expG_{h,u}}$ represent the electrical energy imported from and exported to the grid at hour h by user u; c_h and p_h represent the cost and the price for exchanging electricity in the community at hour h; PUN_h and P_{zh} represent the national uniform price and the zonal price at hour h.
The optimization of the objective function is subjected to several constraints, that allow also the consideration of the eventual presence of storage systems, schedulable and non-interruptible loads, but in the following list just the major constraints are reported.

- Equality Constraints
  - Energy balancing of every user u at hour h.
  - Energy balancing of the energy exchanged within the community.
- Inequality Constraints
  - The total imported energy, both from the community and the grid, for every user u at hour h must be lower than the maximum energy allowed by the Point of Delivery.
- Upper and Lower Bound of Variables
  - The energy exported to the community $E_{expG_{h,u}}$ and to the grid $E_{expG_{h,u}}$ by every user us at hour h must be positive.
  - The energy imported from the community $E_{imp_{h,u}}$ and from the grid $E_{impG_{h,u}}$ by every user u at hour h must be positive and lower or equal than the maximum energy allowed by the Point of Delivery.

The results of this optimization model, that is called *unified model* in the analysed study, can be compared to those obtained by running the same optimization model, but by neglecting the exchange of energy among community members: this scenario, to which we will refer to as *separate model*, basically implies the presence of single prosumers not involved in a community. As it is possible to observe from Figure 3, the unified model allows a better coordination between the production and the demand, leading to an optimal usage of the resources and significant savings in terms of money, with respect to the scenario considered in the separated model.

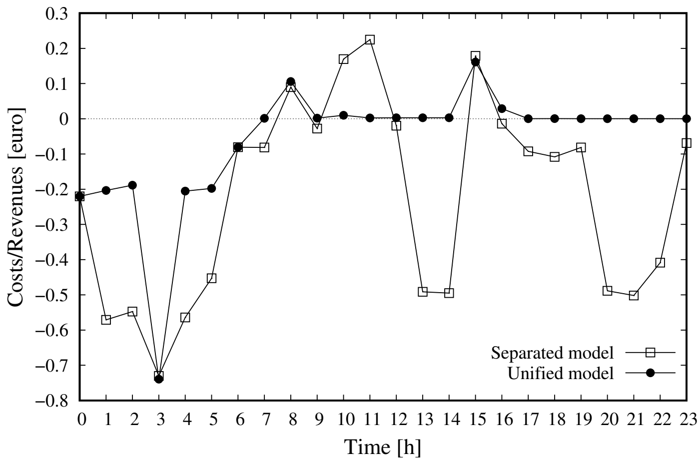

Figure 3: Total costs of consumers in unified and separate models

5.2.3 Division of Profits among Community Members

Another issue that is being currently discussed about Renewable Energy Communities is related to the division of the profits gained by the community among the community members. Among all the possible solutions, a study carried out by the Polytechnic of Turin in Italy [14] identifies three possible profit sharing mechanisms by correlating the amount of profit with the amount of virtual shared electricity that is computed with different logic.

- Sharing Mechanism 1: The community profit is distributed among all community members according to their ownership share of generation plants, regardless of their actual contribution to the shared energy in the community. The main disadvantage of this approach is that it does not consider the effort of individual members to maximize the amount of shared energy in the community.

- Sharing Mechanism 2: The community profit is distributed among all community members according to their contribution to consume the electricity generated by the community plants. The amount of shared energy that is consumed by every user can be computed by means of an optimization model that takes into account the number of consumers, their demand and the available amount of shared electricity for each billing period.

- Sharing Mechanism 3: The community profit is distributed among all community members according to both their ownership share and their contribution to consume the shared energy. In fact, the profit is influenced by two terms: the first one is related to the ownership rights, as in first sharing mechanism, while the second term is gained due to the contribution to the consumption service, as in the second sharing mechanism. This sharing scheme implies that community members are treated differently, according to their contribution to the community funding.

6 Conclusions

After this analysis, it has been clear that Renewable Energy Communities represent a powerful tool in order to contrast some of the main issues that our society is facing today by providing precious social, economic and environmental benefits. Their position in the current regulatory framework and the effort sustained for their incentive make them one of the more discussed solutions that is expected to grow in the next years. Nevertheless, the actual implementation of Renewable Energy Communities is still lacking today, leading to the necessity to overcome their main related challenges in order to fully accomplish their development in the future.

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