Microgrids Models for the Aggregation of End-Users in Energy Communities

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***Abstract*— We know that the energy transition refers to the current electrification of consumption and the parallel decarbonization of the electricity that powers it. The transition model is called also of the 3D: decarbonization, digitalization and decentralization. An important role is played from the digitalization and smartization of the grids that permit the flexibility of the demand. In the future it will be increasingly possible to produce energy closer to where it is consumed, extending the transformation of passive consumers into active consumers, either directly or through aggregations. An important share of energy consumption is due to residential, tertiary and commercial buildings. The so-called end-users. Recent European Directives highlighted clearly the role of the end-users as active players of the system. The goal of this paper is to highlight the advantages of distributed generation combined with the possibility of aggregation of users, transforming the electrical infrastructure into an aggregate of mini and micro networks in an energy communities scenario. In this scenario, the electricity transmission and distribution networks are destined to profoundly change their role, which will be that of guaranteeing a reliable connection capable of allowing exchanges between the various generations of electricity and overcoming the criticality deriving from the aleatory nature of some renewable sources. Pending the complete transformation of the system, the paper proposes a classification of smart microgrids models for the aggregation of the end-users in energy communities. The paper proposes an hybrid model of microgrids, based on a DC common power sharing generation, particularly suitable for multi-unit residential buildings that are the majority of residential infrastructures in our urban centers.**

Keywords—Energy communities, Physical aggregation, Partial aggregation, Virtual aggregation; Hybrid aggregation, Power sharing model

I. Introduction

The green transition and recent increases in the cost of energy are driving a complete reorganization of systems related to the residential sector [1]. Housing units, which previously only served the function of passive loads without any kind of generation and/or storage, are now evolving by increasingly introducing photovoltaic-type systems and battery storage, in order to make themselves more autonomous from the main grid, gaining economic and environmentally sustainable energy benefits. We can divide the housing units in the area into 3 major categories:

1) Isolated residential unit (IRU)
2) Functionally indepentend housing unit (FIH)
3) Housing unit in Multi Unit Residential Building (MURB)

From the regulatory point of view, isolated residential units certainly have greater advantages in that users can choose completely independently the forms and types of systems to be installed without any kind of limitation. The main systems that can be installed within a single unit are: - Electrical powered HVAC; - Induction stoves; - Building automation, TLC and ICT systems. The systems that can be installed only in an IRU are: - Vehicle charging systems; - Photovoltaics.

In relation especially to self-consumption energy generation systems such as photovoltaic energy, IRUs are configured as sole producers and sole consumers, having precisely no need to share the energy produced with other consumers. A decidedly different case is that of multi-unit residential buildings because of issues related to the management and sharing of common installations. These types of housing units, predominant in large cities, present critical issues when deciding to install, for example, a common photovoltaic system, given the difficulty of distributing the power generated by the system to the different utilities. Consequently, while in IRUs the design of the microgrid is simpler, in MURBs a thorough plan is required that includes a feasibility study including the logics of managing the common power, the use of any storage storage, and the heat pump.

II. Aggregation of End-Users: legal aspects

The ecological transition is at the center of scientific and even legal debate [1]. One of the instruments to achieve this goal is the Energy Communities, which in Italy, despite their novelty, have already become fairly widespread (20 in 2021, according to Legambiente). In a nutshell, existing Energy Communities involve public and private subjects (consumers or companies) who join together to self-produce electricity from renewable sources and exchange it among themselves. Recent studies estimate that, also thanks to generous tax incentives, by 2025 Italian CEs will be over 40,000 and will involve 1.2 million households, 200,000 offices and 10,000 SMEs. According to ENEA's guide to energy communities, by 2050 264 million EU citizens will join the energy market as prosumers (a neologism indicating the consumer who is in turn a producer, an expression famously coined by Toffler, 1987), generating up to 45% of the electricity from renewable sources fed into the public distribution system, and thus making a decisive contribution to achieving climate neutrality [2],[3],[4]. In the legal field, energy communities

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have so far mostly been studied focusing on administrative and environmental law profiles (procedures for interconnection and obtaining benefits). Rare, on the other hand, are the studies devoted to the different, but fundamental, profile of the internal relations between community participants and the rules applicable to their possible conflicts. The affirmed neutrality of the European discipline, which merely requires energy communities to be 'autonomous subjects' with respect to their members, leads one to consider the legal form adopted as irrelevant. Analyzing, however, the requirements for energy communities that the European discipline itself sets forth (e.g. that of at-will withdrawal or the necessarily mutualistic purpose) opens up ample space for reflection for scholars of the law of private organizations. The novelty of the phenomenon and the embryonic state of the first projects lead one to consider it opportune to conduct an interdisciplinary study, involving the cooperation of jurists and electrical engineers, aimed at investigating in close connection the problems of the law of private organizations connected to the regulation of energy communities together with the technical requirements they pose. To tell the truth, self-production of energy has indeed very ancient roots, even in Italy. The first Italian energy community can be considered the Società Elettrica in Morbegno, founded in Valtellina in 1897 and still active with 8 hydroelectric plants. Then there were numerous Electric Cooperatives established in the first half of the 20th century (Coop. El. Alto But, in 1911; Az. En. Prato coop., in 1926; Coop. El. Gignod, in 1927). In Europe, the most prominent examples are to be found since the 1970s in Denmark, with wind energy cooperatives [7].

Some recent regulatory innovations at European level have given new impetus to a phenomenon that, as we have just seen, already existed in practice. The European Union, in fact, has long placed the role of so-called prosumers at the center of its energy strategy, with ample space dedicated to community energy projects (a summary in Cusa, 2020).

From a more general point of view, the phenomenon of energy communities must be framed within the energy transition process underway in the EU since 2016, with the presentation of the package of 8 directives "Clean Energy for all European" (for a general overview see in the italian legal literature Ammannati, 2018) and, even more to the point, of the more general process of disintermediation of activities and functions that, until the end of the last century, were considered structurally centralised (the idea of the 'third industrial revolution' prophesied by Rifkin, 2011) [8].

With more specific reference to energy communities, the Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (the 'Directive') stands out. Article 2, no. 16, defines a 'Renewable Energy Community' as any legal entity whose objective is to provide community-based environmental, economic or social benefits to its shareholders or members or to the local areas in which it operates, rather than financial profits. According to the Directive the energy community is based on open and voluntary participation, is autonomous and is controlled by shareholders or members who are in the vicinity of the renewable energy production facilities owned or developed by the community. Art. 16 of Dir. (EU) 2019/944 on the internal electricity market also regulates energy communities from the point of view of grid interconnection, which, however, as mentioned above, entails different legal problems of administrative and environmental law [9]. Article 22 of the Directive regulates inside aspects of energy communities, stating that member states must ensure that they can produce, consume, store, sell and trade energy produced within the community itself. To this end, member states must provide "rules to ensure fair and non-discriminatory treatment of consumers participating in an energy community" [10]. The reasons for introducing the figure of the energy community are set out in recital no. 71 of the Directive, which considers the problems associated with inappropriate ownership of communities, by: (i) allowing Member States to choose "any form of entity for renewable energy communities provided that such entity can, acting in its own name, exercise rights and be subject to certain obligations"; (ii) recommending, in order to prevent abuses and ensure broad participation, the maintenance of the ECs' autonomy 'from individual members and other traditional market actors participating in the community as members or shareholders, or cooperating by other means, such as investment'; (iii) also recommending that 'participation in renewable energy projects should be open to all potential local members on the basis of objective, transparent and non-discriminatory criteria' [11]. The Italian legislature initially gave provisional implementation to the Directive with Article 42-bis of Decree-Law 162/19, converted into Law 8/2020 according to which, pending final transposition, in implementation of Article 22 of the Directive it was permitted to set up energy communities by natural persons, SMEs, and territorial/local entities, provided that participation in the community itself did not constitute the principal commercial/industrial activity of the 'members or shareholders'. The regulation laid down various provisions concerning the interconnection of the EC in the national electricity system and in paragraph 5(c) stipulated that the members/shareholders of the EC 'shall regulate relations by means of a contract under private law', which, in addition to ensuring withdrawal 'at any time', 'unambiguously identifies a delegated party, responsible for the allocation of the shared energy'. The implementation of these provisions was delegated to ARERA (Regulatory Agency for Energy, Networks and Environment), which issued Resolution 318/2020/R/eel, in which it recognized the possibility of setting up CEs in any legal form (third sector body, association, cooperative, consortium, non-profit organization, benefit company, s.r.l., temporary association of companies) as long as they are capable of autonomously exercising rights and being subject to obligations, as well as advocating the establishment of 'Energy Community Cooperatives'. These provisions were then implemented by Article 31 of Legislative Decree 199/2021, transposing the Directive, which confirmed the subjective autonomy of the EC with respect to its members. Lastly, the topic of energy communities has also been widely emphasized by the National Recovery and Resilience Plan (PNRR) in the M2C2 measure (Mission 2, Component 2), which concerns renewable energy, hydrogen, grid and sustainable mobility, with funds amounting to 23.7 billion euro, which expressly envisages the achievement of decarbonization goals by accelerating the development of ECs and small-scale distributed systems (Ronchetti-Medugno, 2021). Energy communities present the jurist with some interesting spaces

for reflection and analysis. The first is to coordinate the technical-application aspects of implementing communities with the legal ones. This is to answer the question (in perspective also de iure condendo) as to whether the current regulatory configuration of energy communities, and in general of the entire electricity distribution system, can incorporate the most appropriate and efficient technical-electrical structure. At present, for example, there is considerable interest in the realization of physical models of electrical microgrids (microgrids) useful for sharing resources within energy communities. Sharing via these microgrids then raises the need to identify with a sufficient degree of clarity what rules should govern exchanges between community members. An even more general problem, however, is that of the compatibility of the numerous possible technical solutions with the current regulatory framework, which is very rigid as it was drawn up in a historical period in which the state of technological evolution (e.g. the impossibility of storage) required the existence of a centralized electricity distribution network to be assumed (and inevitable). This technological assumption led the Italian legislator, by the end of the last century, like others (e.g. the German legislator), to provide the remuneration of the centralized distribution system and, over time, the coverage of all the numerous forms of incentive for energy production (renewable and otherwise), should take place, instead of through general taxation (as is the case, for example, in France), through the so-called 'system charges', charged to each end consumer in the bill. This method of remuneration and financing is, however, difficult to reconcile with forms of energy sharing in restricted user communities (which, not by chance, have historically always been opposed, at least until the need, most recently, to transpose European regulations). The issues of the regulatory impact and of the pricing and valorization of electricity shared in communities or aggregations of users are, therefore, in our opinion, crucial in the general framework of the 'transition' towards more evolved forms of energy networks.
The second profile of interest to the jurist is, instead, more strictly one of company law. It focuses on the compatibility of the European principle of indifference of the subjective forms that can be adopted by energy communities with: (i) the affirmed mutualistic/altruistic purpose, such that one wonders whether it is possible to set up ECs using the subjective forms of normally profit-making enterprises; (ii) their open character, both incoming and outgoing; (iv) the obligation to contract with anyone; (v) their necessary entrepreneurial character, with the consequent need for the activity to be carried out at least economically; (v) the role of possible public partners; (vi) the necessity that natural persons qualifying as prosumers always participate; (vii) the necessary independence of the EC, such that it cannot be subject to management and coordination activities. All these questions are part of the more general and increasingly widespread phenomenon whereby the organizational forms of ordinary profit-making companies or cooperatives are used to pursue solidarity or, in any case, socially useful purposes (on this point see Marasà, 2015; Id., 2017), to the point of legitimizing the identification of a category of 'community' cooperatives (on which see Capo, 2021).
To date, in the face of a relevant commitment of engineering and economic doctrine, in the legal sphere contributions on energy communities are more descriptive of regulatory novelties (Ferrero, 2020; under an administrative law profile Bevilacqua, 2020), with more attention paid to the older, but rather different, phenomenon of electric cooperatives (for a clear exposition of the differences between the two models Osti, 2017) and relatively few contributions with a broader problematic scope (Cusa, 2020; Meli, 2020).
At the methodological level, it should be noted that the common European matrix of the figure calls for a comparative analysis that, through a careful examination of sources, case studies and doctrinal elaborations, allows for the identification of problematic aspects and the formulation of intervention proposals for the solution of common problems (Frieden et al, 2019; Sokolowski, 2019; Tricarico, 2018) [12].

III. Aggregation of End-Users: microgrids types

The authors suggest a classification of the microgrids for aggregation of end-users in 4 forms: physical, virtual, hybrid and partial, each with completely different characteristics and philosophies from the others. The energy communities introduce important benefits for both end-users and distributors. The main benefit for the end users is the reduction of the energy costs, the main benefit for the distributor is the increasing of the demand flexibility.
In order to define the different types of energy communities, it is necessary to start from a basic condominium model (Figure 1). In such a model there is no form of aggregation and energy generation, each user is physically and virtually separate from the others, and the thermal part does not involve modern heat pumps but is entrusted to gas-fired systems [14].

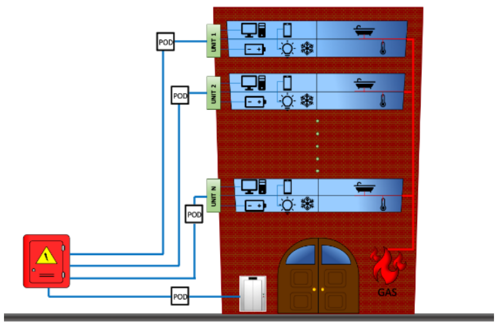

Figure 1. Basic model

In relation to the ways and types of connections of the various utilities, it is possible to classify 4 different types of aggregations, thus corresponding to 4 different types of energy communities:

1) *Physical aggregation*

In this first type of aggregation (Figure 2), there is no separate delivery point for each utility or service but in fact everything is connected in a single framework with a single POC. The metering of energy withdrawn from the grid is therefore not nominalized by utility but total, which causes difficulty in cost allocation and unequal distribution of energy from common PV generation. Since this is an extremely simple type of connection, physical aggregation is also the most economical to implement from a construction and materials perspective. From the figure, an example of this energy community model can be analyzed in detail. In yellow is the connection related to the photovoltaic system, in blue are all the connections referring to the electrical system (in particular, the connection to the elevator represents the common services typical of an apartment building), and finally the connections in red represent the thermal system, which in this example qualifies in a modern heat pump.

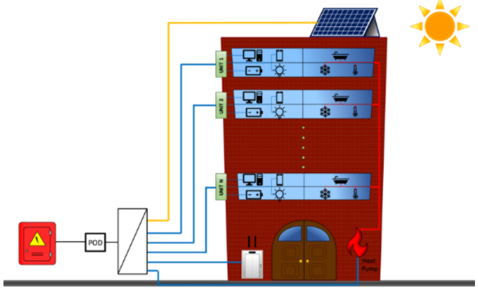

Figure 2. Physical aggregation model

2) *Partial aggregation*

The second form of aggregation is called partial aggregation (Figure 3) and is the first form of energy community with a separate delivery point for each utility. Each apartment in the condominium is thus individually connected to the grid but has no form of connection to the PV system. In fact, the renewable generation system is connected in such a way as to supply the common services (elevators, lights, etc..) and also to the heat pump, selling any excess energy to the grid through its own delivery point. In this form of aggregation, therefore, the utilities only partially take advantage of photovoltaic generation, having to compulsorily supply the electrical loads always from the grid.

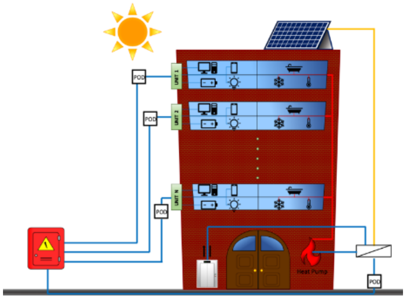

Figure 3. Partial aggregation model

3) *Virtual aggregation*

Virtual aggregation (Figure 4) provides that, as in partial aggregation, each utility has its own energy delivery point. It differs from the latter, however, in that it bases its operation on an almost entirely virtual energy-sharing concept. The utilities always draw from the grid, while the PV system gives up all the energy it produces to the grid, feeding at most common services (or, as in the model in Figure 7 not even those). From the point of view of energy optimization, this model finds little acceptance because the utilities do not benefit directly from local generation. However, it could still be an economically viable alternative because of the incentives made available for the implementation of this specific form of aggregation. In fact, for this specific model there are incentives of up to 10 cents more per kWh shared, in addition to the variable selling cost of energy, which correspond to considerable savings in the bill for each user.

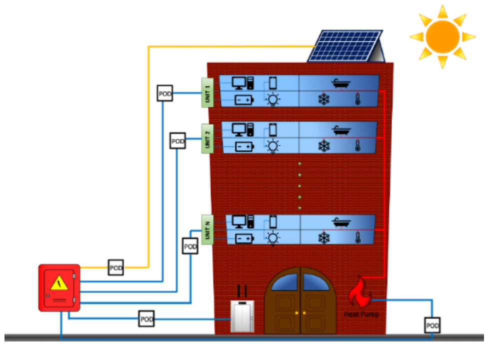

Figure 4. Virtual aggregation model

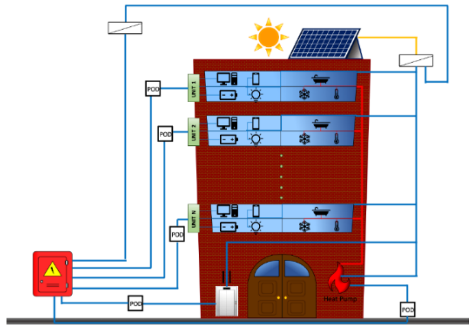

Figure 5. Hybrid aggregation model

4) *Hybrid aggregation*

The last form of energy community that is proposed is based on the hybrid aggregation model (Figures 8). While always maintaining for each utility a separate delivery point connected directly with the grid, there is also a direct connection between the utilities and the PV generation plant. The energy generated by the common PV plant, before being sold to the grid is then sent to the utilities that need it, to the common utilities and possibly to the thermal generation plant via a heat pump. In this way, self-consumption of the energy produced is favored in the most total form, and only any remaining energy is sold to the grid. The ways of allocating the energy produced by PV to the various utilities can be multiple, such as that of the Power Sharing Model and are analyzed in detail in [15]. Compared with the other forms of aggregation, hybrid presents considerable implementation difficulty and higher costs because if the connection between PV and utilities is made in DC several appropriately sized inverters are required to control the power flows.

IV. Economic Analysis and Energy Cost

The aspect concerning energy costs in relation to end users and different forms of aggregation of energy communities is now analyzed in detail. Recently, energy has undergone significant cost increases as never before, and as things stand today, these values do not hint at decreasing. As is well known, the costs of electricity and thermal energy, which the end user has to pay, are a function of several factors that include taxes, management and transportation.

Considering for now only the electricity component, that is, that value devoid of any form of increase and an exclusive function of the market, we can analyze what has been the substantial increase in the last 12 months, referring to the period April 2021 - April 2022 (Figure 6).

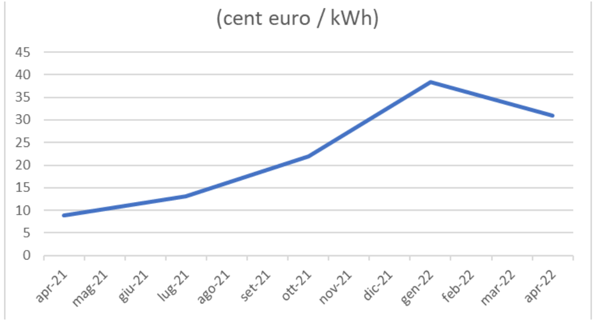

Figure 6. Energy cost (kWh) during past year

As shown in the last graph, the cost of the energy component alone rose from 10 cents/kWh to a peak of 38 cents/kWh and then decreased slightly but remained very high. These values, however, as already mentioned are not the final values, but market values to which all the expected charges will have to be added. Regardless of the type of aggregation proposed, it is initially possible to define the total cost of energy as the sum of the individual contributions arising from the different forms of energy used within the apartment, that is, trivially, electricity and (if still present) that derived from the combustion of methane gas. We can therefore in a first approximation write:

(1) $CE_{tot} = CE_{elettr} + CE_{term}$

Four main items are recognized for the cost of electricity:

(2) $CE_{elettr} = PED + GC + SC + TAXES$

Where PED is the cost of the energy component alone (referring to Figure 6), GC are the transmission and distribution costs, SC are the system charges, and TAXES are the additional taxes. Energy derived from gas also follows a similar process, albeit with different costs related to the transportability and management of that element. Obviously, since they are not absolute and fixed, energy costs are a function of time, and consequently (1) becomes (3):

(3) $CE_{tot}(t) = CE_{elettr}(t) + CE_{term}(t)$

In a traditional basic apartment model, where gas still plays an important role in the total energy, the $CE_{term}(t)$ component is definitely significant, while it is almost completely absent in new apartments where, due to the presence of the heat pump and induction plates, the energy demand is 100% electric. Wanting to analyze the individual energy contributions in detail, it is possible to break down $CE_{elettr}(t)$ and $CE_{term}(t)$ in (4) and (5):

(4) $CE_{elettr}(t) = \sum_{i=1}^{n} CE_{elettr}(t)_{\,i}$

(5) $CE_{term}(t) = \sum_{i=1}^{k} CE_{term}(t)_{\,k}$

Where contributions on electricity are mainly given by: - General private living uses (Lights, washing machines, oven, etc...); - General common condominium uses (Lights, elevator, etc.); - Air conditioning ; - Kitchen stoves (only if induction hotplates); - Domestic hot water (only if heat pump is present); - Heating (only if heat pump present). On the other hand, contributions on thermal energy are given mainly by: -Cooking stoves (only if gas); -Hot water (only if no heat pump present); -Heating (only if gas heating). It is now necessary to consider energy shared and/or sold to the grid, which can contribute to significant savings in the total cost of electricity. In the energy community models considered in Chapter 2, PV generation can have only two end uses:

1) Can be self-consumed by individual users and/or used to feed common services.

It can be released and then sold to the grid

Obviously, the proportion between 1) and 2) depends on the type of energy community realized.

Thus, we can write the energy produced by the PV system, i.e. E_{sh} as the sum of the energy self-consumed ($E_{sh_{auto}}$), the energy sold to the grid ($E_{sh_{sold}}$) and the energy used for common services ($E_{sh_{common}}$):

(6) $E_{sh}(t) = E_{sh_{auto}}(t) + E_{sh_{sold}}(t) + E_{sh_{common}}(t)$

A generalized cost formula can then be written for each user, including all the items above (7):

(7) $CE_{tot}(t) = \sum_{i=1}^{n} CE_{elettr}(t)_{\,i} \sum_{i=1}^{k} CE_{term}(t)_{\,k} + -CE_{sh_{auto}}(t) - CE_{sh_{sold}}(t) - CE(t)_{sh_{common}}(t)$

Note that since this is a cost function formula, all those from PV energy are introduced with a negative sign, as they contribute to the savings for each user.

V. Case study: total cost per user/year

Having analyzed what are the general cost indices, we now want to apply the formulas seen in Chapter 3 to properly calculate the annual energy cost for each user with reference to the type of energy community aggregation.

Table I shows data for a user in a building with a "basic model," that is, without any form of aggregation or generation and where there is still the use of natural gas.

TABLE I. BASIC MODEL WITH NATURAL GAS

		Electricity			Natural gas		
		KE	Yearly Energy		KT	Yearly Energy	
		kW	kWh	Euro/year	kWT	NMC	Euro/year
Unit	Residential uses	4,5	3000	750,00 €			
	Cooking			- €		200	80,00 €
	DHW			- €	30	800	320,00 €
	AC		1500	375,00 €			- €
Total for 1 unit			**4500**	**1.125,00 €**		**1000**	**400,00 €**
Total building			90000	22.500,00 €		20000	8.000,00 €
Common services	Common uses	6	6000	1.500,00 €			
	Winter heating				300	50000	20.000,00 €
Total Common Services				**1.500,00 €**			**20.000,00 €**
Total			102000	24.000,00 €	300	71000	28.000,00 €
Total for 1 unit	**2.600,00 €**						

With reference to the calculation, the condominium under consideration consists of 20 identical dwellings. The final cost represents the annual total for each utility, and since no intervention has been implemented it is logically very high.

In contrast, Table II shows the case of partial aggregation, which is the second energy community model seen in Chapter 2. In this case, the use of gas disappears completely in favor of a heat pump and photovoltaic generation (to be precise, 50 kW nominal) is introduced. In accordance with what was specified earlier, in partial aggregation much of the renewable energy is sold to the grid, while only that which is used to power the heat plant is used by the users.

TABLE II. PARTIAL MODEL WITH HEAT PUMP AND PV 50 KW

		Electricity		
		KE	Yearly Energy	
		kW	kWh	Euro/anno
Unit	Residential uses	6	3000	750,00 €
	Cooking		300	75,00 €
	DHW		1000	250,00 €
	AC		1500	375,00 €
Total for 1 unit			**5800**	**1.450,00 €**
Total building			116000	29.000,00 €
Common services	Common uses	6	6000	1.500,00 €
	Winter heating	50	70000	17.500,00 €
Total Common Services				19.000,00 €
Total			199300	48.000,00 €
Generation	PV	50	65000	
	Self Consupmtion	30%	19500	4.875,00 €
	Fed into the grid	70%	45500	2.275,00 €
	Cash flow			7.150,00 €
Total Common Services				11.850,00 €
Total for 1 unit	**2.042,50 €**			

Compared with the previous case, the introduction of PV and the use of heat pump contributes to a savings of 23% per year in total energy cost. In the third case (Table III), the same condition was maintained (centralized heat pump and PV 50 KW) but the mode of energy community was changed from partial to virtual. There is a further saving compared to the partial model of 10 percent, a saving mainly due to the fact that, as mentioned earlier, energy sold to the grid through the virtual model is valued economically much more than in the other forms of aggregation that instead prioritize self-consumption. Finally, Table IV shows the latest cost analysis for the hybrid model, with a completely opposite philosophy to the virtual model.

TABLE III. VIRTUAL MODEL WITH HEAT PUMP AND PV 50 KW

		Electricity		
		KE	Yearly Energy	
		kW	kWh	Euro/anno
Unit	Residential uses	6	3000	750,00 €
	Cooking		300	75,00 €
	DHW		1000	250,00 €
	AC		1500	375,00 €
Total for 1 unit			**5800**	**1.450,00 €**
Total building			116000	29.000,00 €
Common services	Common uses	6	6000	1.500,00 €
	Winter heating	50	70000	17.500,00 €
Total Common Services				19.000,00 €
Total			199300	48.000,00 €
Generation	PV	50	65000	
	Self Consupmtion	0%	0	- €
	Shared	80%	52000	7.800,00 €
	Fed into the grid	100%	65000	3.250,00 €
	Cash flow			11.050,00 €
Total Common Services				7.950,00 €
Total for 1 unit	**1.847,50 €**			

TABLE IV. HYBRID MODEL WITH HEAT PUMP AND PV 50 KW

		Electricity		
		KE	Yearly Energy	
		kW	kWh	Euro/anno
Unit	Residential uses	6	3000	750,00 €
	Cooking		300	75,00 €
	DHW		1000	250,00 €
	AC		1500	375,00 €
Total for 1 unit			**5800**	**1.450,00 €**
Total building			116000	29.000,00 €
Common services	Common uses	6	6000	1.500,00 €
	Winter heating	50	70000	17.500,00 €
Total Common Services				19.000,00 €
Total			199300	48.000,00 €
Generation	PV	50	65000	
	Self Consumption	90%	58500	14.625,00 €
	Fed into the grid	10%	6500	325,00 €
	Cash flow			14.950,00 €
Total Common Services				4.050,00 €
Total for 1 unit	**1.652,50 €**			

This form of energy community, in terms of cost, is the one that is by far the most cost-effective, with savings compared to the basic model of 37 % due to optimization in the priority allocation of the power generated by photovoltaics to the various utilities. Indeed, it can be seen that in this case 90% of the renewable energy produced goes to supply the requesting utilities while only 10%, or the excess, is sold to the grid at the market price. Figure 7 shows a comparative graph of the four situations seen in the tables.

VI. CONCLUSION

The paper presents a review of technical, legal and regulatory aspects of energy communities. In the presence of a separate and independent housing unit, it is extremely easy to manage a renewable generation system such as photovoltaics, whereas, if such a system is installed in multi-user apartment buildings, energy management in this shared case as seen is anything but simple. The authors suggest a classification of the microgrids for aggregation of end-users in 4 forms: physical, virtual, hybrid and partial, each with completely different characteristics and philosophies from the others. The energy communities introduce important benefits for both end-users and distributors. The main beneift for the end users is the reduction of the energy costs, the main benefit for the distributor is the increasing of the demand flexebility. The data reported in Chapter 4 show considerable savings at the acts of the hybrid model compared to the virtual, the partial and, of course, the basic model without any form of aggregation. It is also true, however, that the virtual model bases its gain on the ability to sell energy to the grid at a significantly higher price than the forms of energy communities; consequently, if incentives grow further, it could become even more profitable than the hybrid.

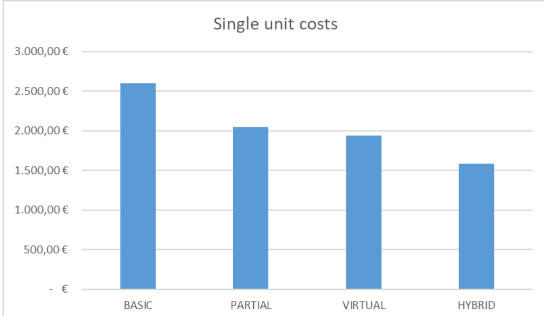

Figure 7. Comparison between 4 models

REFERENCES

[1]. Cusa E., Sviluppo sostenibile, cittadinanza attiva e comunità energetiche, in Rivista ODC, 2020, 71

[2]. Toffler A., The Third Wave, Randoum House, 1987

[3]. Ammannati L. (ed.), La transizione energetica, Giappichelli, 2018

[4]. Rifkin, The Third Industrial Revolution, Griffin, 2013

[5]. Capo G., Le cooperative di comunità, Giur. comm., 2021

[6]. Ferrero E., Le comunità energetiche: ritorno a un futuro sostenibile, Ambiente & sviluppo, 2020

[7]. Bevilacqua C., Le comunità energetiche tra governance e sviluppo locale, AIC, 2020

[8]. Osti G., Energia democratica: esperienze di partecipazione, Aggiornamenti sociali, 2017

[9]. Meli M., Autoconsumo di energia rinnovabile e nuove forme di energy sharing, Nuova giur. civ. comm., 2020

[10]. Frieden et al, Collective self-consumption and energy communities, RESCoop Working Paper, 2019

[11]. Sokolowski M.M., Renewable Energy Communities in the Law of the EU, Astralia and NZ, in Eur. En. & Env. Law Rev., 2019

[12]. Tricarico L., Community Energy Enterprises in the Distributed Energy Geography, Int. Journ. Sust. En. Planning & Management, 2018

[13]. Liberati F., Di Giorgio A, Giuseppi A, Pietrabissa A, Habib E, Martirano L "Joint Model Predictive Control of Electric and Heating Resources in a Smart Building" IEEE Transactions on Industry Applications volume 55, 2019

[14]. Loggia R., Kermani M, Araneo R., Borello D, Panella M, Martirano L., "A Hybrid Energy Hub Investigation with Renewables and Electric Vehicle in a Smart Microgrid Lab" 2021 IEEE International Conference on Environment and Electrical Engineering.

[15]. G. Di Lorenzo, L. Martirano, R. Araneo, L. Cappello, G. Mingoli, F. Ermellino, "Democratic Power Sharing in Renewable Energy Communities: Engaging Citizens for sustainable energy transition", IEEE International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), Bari 2021.

[16]. Loggia R., Lelli F., Pizzimenti F., "A Comparison between Power Splitting Functions Integrated in a Power Sharing Model" 2022 IEEE International Conference on Environment and Electrical Engineering

[17]. G. Di Lorenzo, S. Rotondo, R. Araneo, G. Petrone, L. Martirano, "Innovative power-sharing model for buildings and energy communities", Renewable Energy 172 (2021).

[18]. L. Martirano, S. Rotondo, M. Kermani, F. Massarella, R. Gravina, "Power Sharing Model for Energy Communities of Buildings", IEEE Transactions on Industry Applications, Vol. 57, No. 1, January/February 2022.