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ORIGINAL ARTICLE

Community Energy for enhancing the energy transition

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ABSTRACT

In the transition process towards renewable energy systems, the way to involve final users in the energy production is still complex. Although many steps forward have been made by Community Energy (CE) around the world and especially in the European Uniion (EU), there are still many entry obstacles that do not allow a revolution in the energy market. After presenting the state of the art on the development of Community Energy in Europe, the main features of community energy have been explored in this paper. This work reports a complete overview of the current perception of Community Energy among people, analyzing the vision that a possible end user could have in approaching this innovative system of energy sharing. To achieve this goal, the paper presents the results of a survey, with the aim of studying how people can be more involved in the energy market and how they could have access to community energy. The outcomes show how people needs should be considered, in order to increase awareness and control over the energy that they consume for better development of future community energy. The current weaknesses and shortcomings in the diffusion of communities are also analyzed, and some suggestions and discussions are made on how to overcome these limitations.

Keywords: Community energy; renewable energy systems; prosumers; electricity distribution grid.

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INTRODUCTION

Energy production based on fossil sources is no longer sustainable for the humankind; every day more and more people understand the importance of their actions in energy consumption and production. Fossil fuels still dominate energy production: in 2016 the world produced 13,764 Mtoe (Million tons of oil equivalent) mainly from petroleum (32.5%) and solid fuels such as coal (26.6%) (IEA 2018) whereas Renewable Energy Sources (RES) accounted for only the 13.6% of total production (REN21 2018). COP21 agreement in Paris fostered many countries to put in action a pivotal change in their energy production mix.

In this context, household and commercial buildings are responsible for up to 40% of the global energy needs (IEA 2018). Furthermore, in the next future, the total energy consumption of buildings is destined to grow. This fact is mainly due to an increase in space cooling and comfort requirements, which will probably lead to more comfortable but energy-intensive buildings. Innovative technologies, such as appliances labelled as energy A-class and HVAC (Heating, Ventilation and Air Conditioning) systems, are avoiding exponential growth but are not enough to cope with Paris COP21 goals. Therefore, further penetration of RES integrated into buildings is necessary.

Community Energy (CE) offers a new opportunity to face this challenge. CEs are a group of final users that decide to become renewable energy producers and consumers boosting the energy transition. Coupling production and consumption allows to enhance benefits on both sides of the energy supply chain by creating a new stakeholder known as Prosumer (an energy producer and a consumer at the same time). CEs are a valuable opportunity to aggregate prosumers sharing common goals and dealing with utility companies in a synergic way. However, many obstacles still exist mainly due to a lack of precise and uniform regulations, to limited final user competencies, to weak engagement of potential shareholders and to the huge investments required (Genus and Iskandarova 2020).

The first part of this paper introduces the regulatory and technological framework of CE, with a particular focus on EU directives, successful CE case studies, systems for conversion, storage and managing of energy. What emerges from this analysis is that technologies are mature and regulatory stakeholders are interested in fostering CEs to enhance the energy transition. However, a crucial role must be addressed by real market and social demand. Indeed, CEs involve a transformation of people into active players of the energy market. The second part of the paper aims to analyse the primary entry obstacles limiting the development of CEs from a user perspective. It is the opinion of the Authors that an active engagement of the people in each and every phase of CE development, from the setup (approaching) phase to the day-by-day operations, is crucial. A questionnaire was submitted to a mixed sample of more thena 400 people to understand methods better and to engage people. The results of the survey were the basis of the Strengths Weaknesses Opportunities Threats (SWOT) analysis discussed in the conclusions section of the paper.

LITERATURE REVIEW AND CURRENT FRAMEWORK

The European Union has set ambitious RES goals in response to the Paris Agreement, which aims at reaching at least a 32% share for RES production by 2030. A massive deployment of intermittent RES will result in a gradual decentralisation of the energy system, causing stability and flexibility issues to the electricity grids. On the other hand, it also represents an opportunity to exploit small on-site renewables installations by allowing homes and small businesses to produce, consume and share the energy generated.

The extensive adoption of RES - directly integrated into the buildings or connected to the energy grids - has increased the variation during time of the energy value (evaluated as consumption of resources, as well as energy tariff). Indeed, the energy value strongly fluctuates during time, even with substantial daily differences, according to the stochastic fluctuations of the energy demand and availability. The more the penetration of renewable source, the more stochastic the energy availability is (Serale, Fiorentini, Capozzoli, Cooper, et al. 2018). Furthermore, it can be observed a mismatch between these stochastic patterns of energy production and consumption (e.g., in building space-heating demand does not occur when solar energy is readily available).

CEs are a potential solution for reducing the geographical and temporal gap between energy consumption and production, as well as a resilient solution for future climate scenarios (Bilardo, Ferrara, and Fabrizio 2019). The definition of Community Energy refers to a wide range of collective energy projects, mainly through RES, aimed at involving citizens' participation in the energy system. Their primary purpose is to provide services to the local community and to engage people in the energy production and consumption processes. CE initiatives have been progressively spreading across Europe. They are planned gradually as ground-breaking approaches to guarantee active citizen participation in the transition toward cleaner energy systems (Francisco and Taylor 2019).

The first CE initiatives were cooperatives for rural electrification initiatives in Germany, Italy, or Spain dating back to the early 20th century (Capellán-Pérez, Campos-Celador, and Terés-Zubiaga 2018; Mori and Spinicci 2010; Yildiz et al. 2015). They have been later associated with RES production with the rise of wind cooperatives in Northern Europe, particularly after the Chernobyl disaster. However, it is after the 2000s only that CEs have been considered as a promising new approach of people engagement in the energy transition toward more decentralised and cleaner energy systems (Creamer et al. 2019). CE initiatives are more common in Northern Europe - particularly Denmark, Germany, and the UK - and far less established in Southern Europe. For instance, more than 800 energy cooperatives are recognised in Germany, accounting for about 34% of the population (Yildiz 2014) whereas in Spain or Greece less than 10 initiatives have been reported in the last years (Capellán-Pérez, Campos-Celador, and Terés-Zubiaga 2018; REScoop MECISE 2019).

CE in Ireland, Netherland and Belgium demonstrated to be able to interact effectively with the electricity transmission grid, proving virtual power plant dispatching services (van Summeren et al. 2020). In England, CEs have been an incentive for the development of solar energy technologies (Nolden, Barnes, and Nicholls 2020). Focusing on a CE in Germany, Hahnel et al. (Hahnel et al. 2019) showed how Peer-to-peer (P2P) exchange of energy generated in a decentralised way is a promising means to optimise renewable energy flows. The paper focuses on 300 homeowners' behaviour, demonstrating that CE electricity prices and state of charge of private energy storages are the critical determinants of their trading behaviour. Capellán-Pérez et al. studied the development of CE projects in Eastern European countries individuating a growing interested in environmental topics, also due to an increase in people salaries (Capellán-Pérez et al. 2020).

Gonzales et al. (Fuentes González, Van Der Weijde, and Sauma 2020) found that CE projects present more opportunities to be implemented in comparison with net billing schemes in Scotland and Chile. In the study the demonstrated that biform games analysis could be a valuable tool to examine increasingly complex electricity markets.

Eventually, CE based on RES demonstrated to be a valuable solution to address particular problems such as the electrification of remote or depressed land, such as islands (Van Der Waal 2019) or rural Indian villages (Joshi and Yenneti 2020).

Candelise and Ruggieri (Candelise and Ruggieri 2020) recently investigated the development of Community Energy in Italy. The study pointed out that the Italian market is still at its niche level. The industry is characterised by small initiatives mostly dependent on national photovoltaics (PV) policy support. Moreover, it underlined how only more significant and national initiatives developing multiple projects and differentiating their activities have managed to continue growing at the time of discontinuity of policy support and contraction of the domestic RES market (Ryan, Donou-Adonsou, and Calkins 2019).

Energy conversion and storage systems in Community Energy

The growth trend of the various RES adopted by community energy in Europe is shown in Fig. 1. The pattern presented demonstrates how the scenario of renewable resources approved by the CE is continuously evolving, displaying an uncertain forecast for future situation (Li et al. 2017).

Hydropower dominated the scenario of renewable production in Europe until the 1960s (QualEnergia 2017). However, the primary limits of hydropower production were represented by restricted territorial availability. Nowadays, micro-hydropower plants remains an excellent solution but limited to the mountain and rural communities (Arnaiz et al. 2018; Kagohashi and Fujimoto 2019). The second half of the twentieth century saw the birth and rise of wind power. The first projects, limited to a single turbine, made it possible to generate electricity for a few families (Gorroño-Albizu, Sperling, and Djørup 2019). Denmark has pioneered the adoption of wind energy RES and is still the home of the most significant number of CE based on this energy source (Bolinger 2001). In the last years, the massive diffusion of photovoltaic (PV) panels, combined with their constant drop in price, has allowed the growth of new communities based on solar power. Furthermore, the distribution and availability of the solar source interested an increasing number of households and small-medium enterprises (Kim et al. 2020). CE based on this source have increased exponentially in recent years, and several business models have been adopted to profit from PV panels (Nolden, Barnes, and Nicholls 2020). Around 34% of the renewable power installed in Germany belongs to individuals or communities (Interreg Europe 2018; van der Schoor and Scholtens 2019).

Less diffused alternative systems are represented by micro-cogeneration, biogas or biomass power plants (Chung, Park, and Coimbra 2014; Pal and Bhattacharjee 2020; Testi et al. 2020) or solar-based systems for the production of domestic hot water (Bilardo et al. 2020) and space cooling (Bilardo, Ferrara, and Fabrizio 2020). The examples of these applications, although less accessible, usually live in the countries of northern Europe, combining electricity production with heat distribution for the community spaces (Rezaie and Rosen 2012).

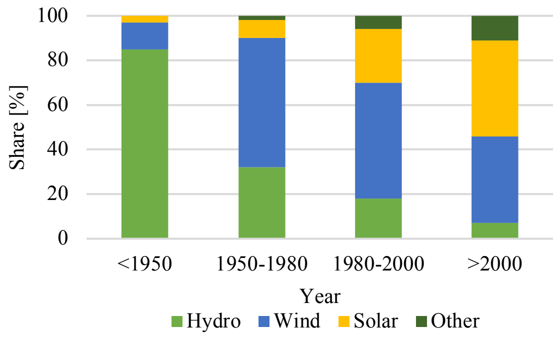

Fig. 1. RES development in CE.

Eventually, future scenarios foresee a drastic decrease in the share of electricity generated by plants owned by large utilities, assuming a transition for the energy market that will be led by communities, small enterprises and households. Fig. 2, based on the data collected in this paper, quantifies a future scenario on the share of electricity production, comparing it with the actual one.

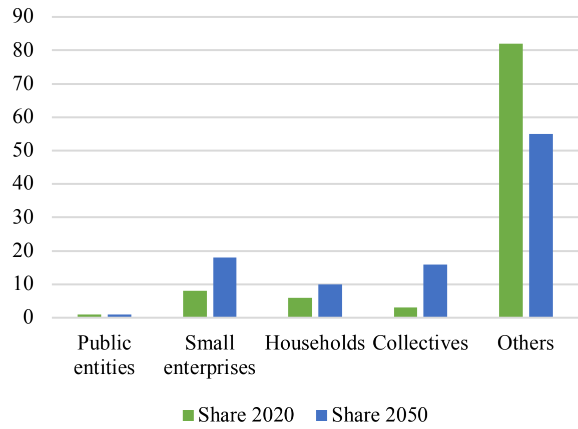

Fig. 2. Share of electricity production by investor type in Europe.

RES introduced the issue of time mismatch between energy production and consumption (Aspeteg and Mignon 2019). In recent years, electric storage units allowed to exploit the variable output of electricity from RES. Electric storage batteries are spreading more and more, as their reliability and capacity are continuously increasing, while the price drops and becomes accessible to an increasing number of communities (Pimm et al. 2020). The main limitation of these applications at the moment is the techno-economic feasibility, also due to the lack of projects developed in different scenarios (Dong et al. 2020), even if the expectations for success are promising (Liang, Shirsat, and Tang 2020).

Apart from electrical batteries for storage, software solutions for demand-side management are useful tools to optimise users' consumption profiles according to energy availability. Data-analytics software solutions can be used in the design stage to classify the demand/supply profiles of the CE participants (Capozzoli et al. 2017) and tune the combination of multi-energy systems (e.g., define the best combination of RES, batteries and energy delivery systems for the specific needs of the community). Furthermore, the collected data can be used in the operating phase for continuous commissioning purposes, the detection of faults occurrence and the re-tuning and optimisation of system controllers. (Serale, Fiorentini, Capozzoli, Bernardini, et al. 2018; Serale, Fiorentini, and Noussan 2020). Eventually, micro-grids managed by intelligent supervisory controllers are a specific sub-cluster of CE completely disconnected from the primary transmission grid (Olivares et al. 2014; Zhou et al. 2020).

Demand Side Management also represents an additional issue when dealing with RES exploitation. Fig. 3 shows some goals for the users' behavioural changes that may be beneficial for a CE. Alskaif et al. (Alskaif et al. 2018) individuated in gamification an innovative tool to achieve these goals. The authors proposed a new framework to increase curstomers engagement in energy applications. In this perspective, modern user interfaces and dashboards can be much more interactive, offering visibility over pre-analysed data, easy to compare with benchmarks and to be used for extracting useful knowledge.

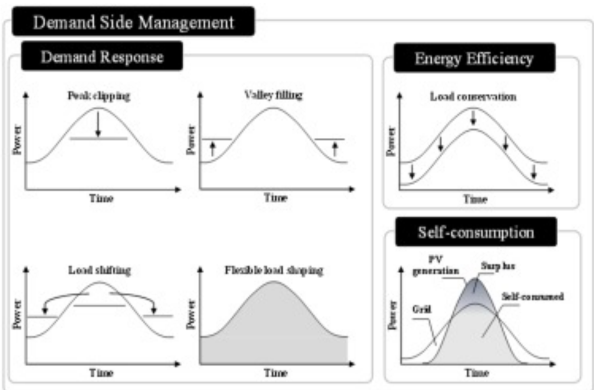

Fig. 3. Demand Side Management strategies for CE (Alskaif et al. 2018).

Regulatory framework

As soon as CEs began to spread, especially in northern Europe, they immediately got attention from governing bodies. One of the first challenges for national governments was to define the legal forms through which CE could be represented. Depending on the country of incorporation, five main legal forms have been identified in European CE (Interreg Europe 2018):

- Cooperatives: formed by a group of individuals who join a CE to derive personal benefits in terms of energy, without economic interests.
- Partnership: the CE is divided into stakes, and each member benefits from the community in proportion to the share it holds. The legal form of partnership allows the generation of an economic profit besides generating energy benefits.
- Foundations: non-profit organisations with the main purpose of generating a social benefit to a community or individuals who cannot afford energy.
- Public utility company: represented by municipalities, mostly agricultural or rural, which invest their citizens' taxes to generate an energy benefit restricted to the community.
- Public-private partnerships: partnerships between public, private and individual citizens who invest in energy production to profit from local energy sharing and distribution.

The development of appropriate policies for the development and dissemination of CE has been gradual and variable from country to country. However, most states that have had to stimulate and support CE development undertook similar regulation over the years, which can be divided into three common policy schemes:

1) Grant: this scheme, usually adopted as the first, consists in the promotion of funds (including non-repayable funds) to promote new CE. The advantage linked to grants is the easy access to finances, low risk of the initial investment and the community ownership of the completed project.
2) Feed-In-Tarifs (FITs): many countries in recent years have promoted remuneration to all communities capable of supplying renewable energy to the grid. Many CE have built business models based on FITs, reaching valid economic targets. However, in many cases the FIT scheme has allowed the introduction of major investors who, attracted by possible remuneration, have forced the creation of CE exclusively based on profit. This mechanism has often been updated over the years, with a gradual decrease in tariffs, until many states have discontinued it.
3) Power purchasing agreement: with this policy model, many states have allowed CE to become real commercial players, allowing communities to draw up sales contracts and generate profits by selling self-produced energy. This model, often adaptable for large-scale projects, has allowed CE to establish a customer-community relationship in different scenarios, spreading the culture of renewable communities in different realities.

Over the years, the European Union has supported the development of national policies in favour of CE growth. The recent Clean Energy Package of the European Commission has defined the rights of citizens and communities to participate in the energy market. Two directives have focused attention on the community energy: Renewable Energy Directive (EU) 2018/2001 recast, also known as RED II has defined the role of the

CE in the energy transition. Besides, the Internal Electricity Market Directive (EU) 2019/944 recast has introduced new roles and opportunities for the generation of electricity by communities. Both directives, recently enacted at the European level, will soon be implemented by the member states, setting out future steps for CE.

Although the policy support for the growth of the CE is continuously evolving, the culture of forming communities of people based on the production of renewable energy is strongly influenced by the country of origin. As reported in Fig. 4, the distribution of CE in Europe is strongly heterogeneous. This trend underlines how the different approaches taken by European countries to support the CE, mixed with a different social perception, led to a highly variable result depending on the country. Considering this, progress in the field of CE is now more than ever underway and new development models are expected in the coming years.

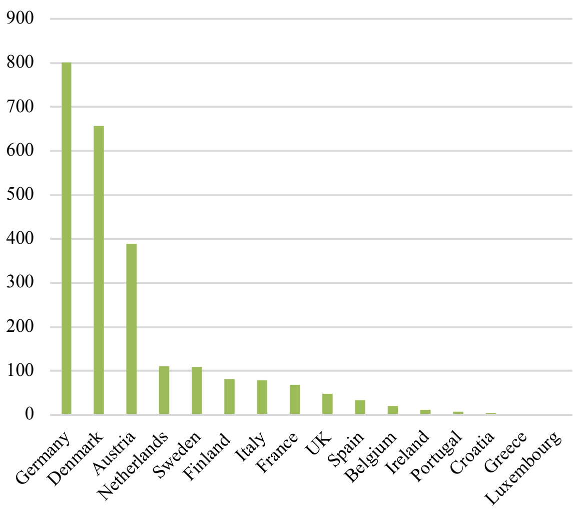

Fig. 4. CE distribution in EU. Adapted from (Bauwens, Gotchev, and Holstenkamp 2016).

METHOD AND DATA

The scope of the analysis carried out in this paper is to investigate the factors limiting the spread of CE in Italy. The literature review highlighted that the technology is mature to permit a distributed installation of RES and the effective managing of CE. Therefore, the cause of the small distribution of CE in Italy had to be sought into social reasons and consumers' willingness to evolve into Prosumers. Authors' hypothesis individuated user engagement as the most critical issue to be solved for enhancing the CE, as also idividuated by psychological studies (Sloot, Jans, and Steg 2018). Two crucial moments were individuated to engage the end-users:

1) The approaching phase;
2) The operational phase, including users' active participation to the CE.

The active involvement in the community is a topic widely discussed by scientific literature (Sanguinetti, Dombrovski, and Sikand 2018). Firstly, engagement is essential for ensuring a positive interaction among participants and avoiding users' abandoning the CE. Secondly, changes in people' behaviours and consumption profiles may improve the shares of self-consumed energy and the overall CE value-stream consequently.

The approaching phase is a decisive moment for a CE since it determines the opportunity (or not) to reach a large cluster of stakeholders and having a significant impact. In this phase, the most important stakeholders are the citizens, which must be transformed from passive energy users to active prosumers. Due to the importance of this phase, the present paper aimed to study the citizens' willingness to take part in a CE project.

To deepen the importance of a CE approaching phase, the work presented in this paper studied the results of an online survey based on 16 questions. The survey was submitted to a population of around 1100 people in Italy randomly selected and with very different backgrounds. The main distribution channels were social media such as Linkedin and Whatsapp groups reaching both direct and indirect acquaintances through the request of sharing. Innovative CEs should also consider the users' active participation in maximising its effectiveness. The survey had a response rate of more than 36% reaching 400+ people in Italy (over 70% in the North of Italy, due to the fact that 5/6 authors come from that area), defined "population" in the following parts of the paper. The age of the population was equally distributed: 5% 18-25; 44% 26-35; 19% 36-50; 32% over 50; the results show differences with the national Italian age distribution, where people over 50 are the 45,4% in 2020 according to ISTAT data (ISTAT 2019). This discrepancy is mainly due to two elements:

1) The kind of distribution channels mainly used by younger people
2) The limited amount of time available for collecting responses

Almost 60% had a title of study degree equivalent. Only 20% was aware of the power production mix in Italy. 88.5% of the population said that was interested in consuming energy produced by RES (61.6% highly motivated) and 78.4% was aware of the opportunities offered by energy sales to the market. Nevertheless, only 15% experienced installation of RES in their households.

Each authors analysed the survey results and integrated with the regulatory framework and technological background discussed above in order to develop a personal Strengths Weaknesses Opportunities Threats (SWOT) analysis. Thereafter all the authors discussed and merged each SWOT analysis finding solution for differences between each of them, achieving a final and aggregated SWOT. The SWOT strategic technique was useful to identify the critical success factors readily. Indeed, the SWOT intended to identify the internal and external factors that are favourable or unfavourable to achieve the scopes of CE. Based on this analysis, readers interested in CE ventures can plan their future efforts in project development efficiently.

An evaluation of the population characteritcs has been performed in order to extrapolate important pieces of information on their influences on the answers selection. Some quick ANOVA analysis have been completed with the most relevant questions. ANOVA allows to determine, with a certain level of risk, the presence of significant factors in the obtained statistical results. This can be used to purificate some undesired influence and deviation from the natural variation of the results. More precisely two key peculiarities of the population involved in the survey have been considered: age and level of education.

RESULTS

This section reports the results based on the questions (Q) submitted (please refer to the Appendix for a detailed overview of the survey). The results collected in this section suggest a well-defined perception that people have of CE and related aspects. A thorough understanding of the individual is, in fact, fundamental to generate innovation within future community energy. The data collected and presented in this section can be considered an observation study, since the survey subjects were not influenced by the authors. The purpose of this statistical survey is to gather information from a sample group as heterogeneous as possible to know the habits of an entire population. In the particular case, the proposed survey is focused on opinions.

The results of the survey explored the awareness and expectations of individuals regarding community energy. Therefore, this section may represent a support tool for design alternative setups to be tested in the future CE, which can be exploited as a starting point for the future development of communities based on energy sharing.

Fig. 5 reports the answer to the question Q9: "What are the difficulties for you to install and produce renewable energy, thus making yourself an energy producer?". Answers showed the most important issues were due to economic concerns, mostly due to the high capital investment required (A) and an economic return often unclear (D). Secondly, people living in apartments were upset to convince other people in the same block of flat (B) to install shared solutions, or they do not have enough space for the installation of energy conversion systems (F). Paperwork and permitting were also important concerns (C) as well as the deficiency of technological background to understand problems and opportunities (E) and to operate and manage the systems (G). Few people said that they are not interested (H) or other answers (I).

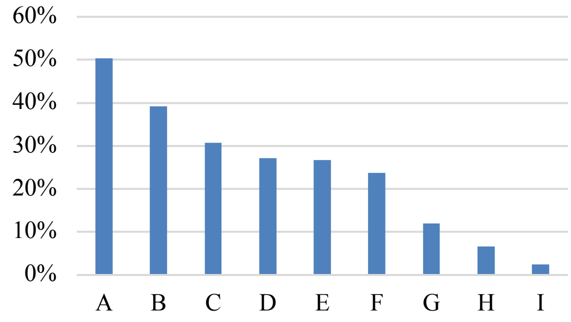

Fig. 5. Difficulties in installing and producing renewable energy.

CE are not widespread in Italy. Indeed, only 31.7% of the interviewed people known CEs as a potential instrument for enhancing the RES installation. However, Fig. 6 shows how 58% of the population have a high interest to in establishing a CE (rate "High"or "Very High").

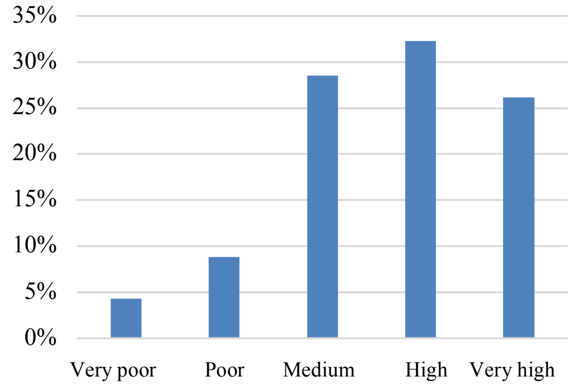

Fig. 6. People desire in CE aggregation.

Fig. 7 refers to the answers related to the question Q12: "What benefits do you expect from joining a Community Energy with other people to produce renewable energy?". Most of the people justified their willingness to be included in a CE as a tool for optimising their power consumptions (A). Secondly, answer (B) showed high expectations in terms of capital investment reduction due to potential scale-effects. Cross sales among participants (C) and reduction of the electricity bills (D) are the other two important economic reasons that might pursue people in aggregating. Reducing dependencies from the centralised system (E) and improving sustainable footprint (F) were also considered important by more than 25% of the population. Eventually, exploiting the CE to interact with people in the neighbourhood was considered a less important aspect.

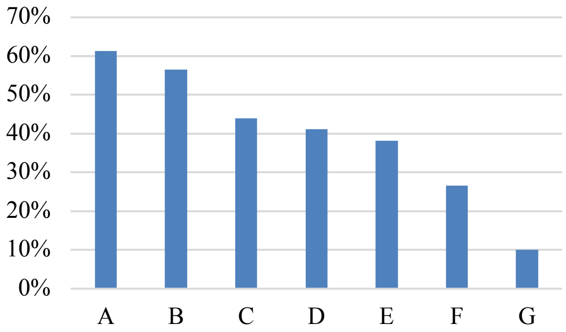

Fig. 7. CE expected benefit.

Eventually, Fig. 8 shows the answer to the question Q13: “What difficulties do you expect from joining a Community Energy with other people to produce renewable energy?”. The most important entry barrier for CE was considered by the low attitude of people in forming groups and communities (A). Most of the interviewed agreed that this aspect could be overtaken with very clear rules and requirements among the participants. Similar to the answers related to RES limitation, permitting, and paperwork (B) and high technical competences required (C) were considered potential restrictions for CEs. Daily concerns were also individuated as possible problems. In particular, the managing of the participants (D) and the operation and maintenance costs (E) both were considered a potential concern for 41% of the population. Finally, incumbents were considered a downside only by 30% of the population.

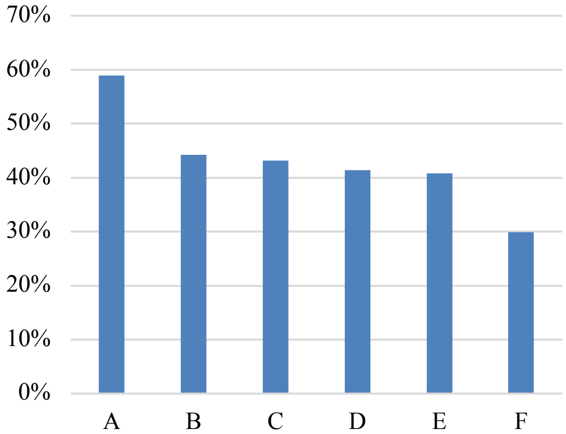

Fig. 8. CE expected troubles.

Evaluating the influence of two key factors (age and education) on the popolutation and their survey answers has been considered relevant. Therefore, a two factors ANOVA analysis, after some elaboration of data via pivot tables, was performed regarding most of the questions. In Tab. 1 and Tab. 2 the analysis on Q3 is shown. The first step (Tab. 1) is related to the calculation of the averages according to a specific factor, while the second (Tab. 2) is the actual data elaboration. It shows the calculation for: Degrees of Freedom (DOF), Sum of Squares (SS) between groups, and Variances of means between groups for the considered factors, where the Casual Errors output was obtained as difference of the previous two from the total. The final step to determine whether the factors were significant for the given population while giving a certain answer was to compare the ratio of variances factor/casual error and compare it to the standard Fisher Value (F limit), calculated according to the input parameters. If the ratio was smaller than the F value it could be determined that the considered factor was significant for the given answers. Due to the characteristic of the survey, a level of risk of 20% was considered appropriate to extrapolate some useful considerations on the population and its possible interests.

Tab. 1. 2-Factors ANOVA Analysis on average outputs of Q3

	Education level							
Age	*Elementary School*	*Secondary School*	*Diploma*	*Bachelor*	*MsC*	*MBA*	*PhD*	*Avg*
>50	2,00	2,38	2,85	2,73	3,33		2,60	2,65
18 - 25			2,20	3,16	2,71			2,69
25 - 35	3,00		2,86		2,95			2,94
26 - 35			2,46	2,77	2,70	3,10	2,33	2,67
Avg	2,50	2,38	2,67	2,89	2,74	3,10	2,47	

Tab. 2. Outputs of ANOVA Analysis on questions Q3

Variation	DOF	SS	Variances	Variance Ratio	F limit
Column Factor	6	4,28E+00	7,13E-01	2,63	1,96
Row Factor	3	5,37E-01	1,79E-01	0,66	2,02
Casual Errors	18	1,90E+00	2,72E-01		
Total	27	6,72E+00	4,20E-01		

A similar procedure, with some corrections for the different kind of answers, has been applied to any significant question. The procedures have been omitted from this paper for easier reading, while the final results have been reported in Tab. 3**Tab. 4.**

Tab. 3. Outputs of ANOVA Analysis on relevant questions

	Factor is statistically Significant? (With risk=20%)	
	Age	Education
q2	No proof	No proof
q3	No proof	Yes
q4	No proof	No proof
q5	No proof	Yes
q6	Yes	No proof
q7	No proof	No proof
q8	No proof	No proof
q10	No proof	No proof

Some expected results as well as some surprises were found. As it could be imagined the level of education resulted to be a significant factor in those answers concerning the level of awareness of technical/economic aspects. The age is significant, also with small risk of errors, in questions related to the use of technology and foreseen obstacles in creation and management of CE too. Surprisingly, we can not state that level of education is a significant factor toward environment sustainability and renewables interests or future intentions, while age is, indicating a possible gradual cultural change in the most recent generations.

The survey discussed above has generated interesting results that can be taken into account for the developments of future CE. Starting and managing community energy is a technical/economic skill that few companies have, and the results of the proposed survey highlight which are the most critical aspects of CE development, especially in Italy (where most of the interviewed sample lives). The high investment costs to support the creation of a CE are often identified as the first entry barrier to overcome. Furthermore, many people are not very confident of the economic (rather than energy) benefits, having an unclear vision of the payback time related to joining a CE. Finally, the limited technical skills on this topic block many individuals in the decision to join a community, since they fail to understand the technology and the concepts that underlie renewables-based community energy.

From the analyses carried out in this paper, a gap can be highlighted between the current state of academic research in the CE field and the real perception of community energy among people. Based on this awareness gap, Tab. 4 has been drawn up. The table summarises the application of a SWOT analysis to the CE, based on the concepts taken into consideration in this paper.

Tab. 4. SWOT analysis for future CE developments and innovation

Strengths	Weaknesses
People awareness People control Boosting RES development Social engagement Energy waste reduction Local economic impact Decentralisation of energy production	Human interaction Paperwork and regulation Consumer behavioural shift People lack of knowledge More complex energy systems Space availability for new installations Proximity constraints between users
Opportunities	**Threats**
Shifting to 100% renewable-systems Demand-side flexibility Integration and balancing of the electrical grid New jobs and business models opportunities People education RES price drop	Customer/community member retention Energy utility monopoly Energy utilities leverage power Members individualism Energy price fluctuation Changeable and unclear regulation

DISCUSSION AND CONCLUSIONS

The first part of the paper outlines how the technological solutions that can support the denergy transition to cleaner sources are largerly available on the market. However, their implementation is slowed down by the energy market that still relies on an outdated infrastructure not allowing end users playing an active role. CEs could solve this paradox, giving people tools to support directly the energy transition.

Simarly to other processes, nowadays innovators are not anymore people providing answers but are those are able to stimulate questions and spread consciousness into people. The approach undertook in the present paper starts from a survey to understand peoples needs, pains and fears trying to figure out how it can be converted into a real demand of technology and innovation.

CE represents a tool of high strengths to generate undoubted benefits not only in the energy sector but also in energy education for future people generations. A crucial asset of the CE is to push towards a decentralised energy production system, where individual users, through their conscious choices, can contribute to the social and economic good of a community. For this reason, the opportunities related to the adoption of the CE aim to combine economic benefits (profit from the energy sale, incentives on production, RES price drop, etc.) with social benefits (education, new jobs, climate change action, etc.).

The analysis carried out in the present paper showed how reliable information and engagement of people will be fundamental for the spread of CEs. Indeed, it has been identified that most people are unaware of the potential of a CE and how they can produce and self-consume renewable energy, although they are interested in the topic. Moreover, the survey highilights how the continuous engagement and information process is a key reading aspect for the future of the CEs. Future experiments should investigate engagement tools capable to position individual CE members in the spotlight, providing them with the skills necessary to interact with the community. Moreover, it will be interesting to inestigate the opportunity to increase people energy awareness and simplify the energy consumption system, which is currently too complicated and understandable for few.

Eventually, CEs have the drawback of stressing the dualism between being individuals and part of the society whose interests often overlap and collide. On the one hand, citizens as part of the society are aware of the impact that their positive actions can have on the future of the planet. On the other hand, idividuals consumers seek to optimise choices to achieve their personal benefit, regardless the sense of community. This dualism is further highlighted within a CE, where everyone is both a citizen and a consumer. A successful CE is able to reconcile these two realities, benefiting from both aspects. Future of the CE will be determined by the active participation of individuals within the society, generating communities of individuals motivated to reduce their energy impact through sharing and self-consumption.

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APPENDIX

The questions (Q) of the survey submitted and used for this research are shown below.

Q1. *General questions about age, gender, origin.*

Q2. *Have you ever heard of Community Energy?*
Y/N

Q3. *How much do you understand your utility bills?*
1-5

Q4. *In your opinion, what are the main problems in the energy market? (more than one answer possible)*
Limited transparency in the offer by utility companies
High system management costs and taxes passed on to the end consumer
Limited transparency in the utility bills
Limited consumer leverage to affect production
Paperwork and permits
Share of renewable energy produced still limited
Limited political interest on innovation issues

Q5. *Do you know how the electricity in your country is produced?*
Y/N/Partly

Q6. *How much are you interested in using electricity from renewable sources?*
1-5

Q7. *Do you owe any renewable energy systems installed (photovoltaic panels, wind turbines, etc...)?*
Y/N

Q8. *Do you know that you can produce renewable energy yourself and resell the excess produced to the grid?*
Y/N

Q9. *What are the difficulties for you to install and produce renewable energy, thus making yourself an energy producer? (more than one answer possible)*
Paperwork and permits
Required upfront cost
Lack of economic incentives
Lack of personal skills
Lack of interest and desire to change
Lack of support tools for system management
I have no space to install a system
I live in a flat and we need a common decision

Q10. *How motivated are you to join in a community (called Energy Community) with other people to produce renewable energy by sharing costs and benefits?*
1-5

Q11. *Whom would you turn to for more information in creating a Community Energy?*
My utility
Internet
Building manager (if you have one)

Q12. *What benefits do you expect from joining a Community Energy with other people to produce renewable energy? (more than one answer possible)*
Discount on the utility bill
Consumption optimisation
Reduction of the environmental impact
Interaction with other community members regarding consumer habits
Sharing of installation and system management costs
Limited dependence on utility companies
Energy exchange between members with economic benefits for both

Q13. *What difficulties do you expect from joining a Community Energy with other people to produce renewable energy? (more than one answer possible)*
Daily management of the community
Technical management of the systems
Installation and management costs
Bureaucracy and permits
Distrust of people to join in a group
Interference of utilities

Q14. *Which are the most important aspects of the management of a Community Energy? (more than one answer possible)*
Management and optimisation software for production and consumption
Support from utility companies
Clear agreements between community members
Support person/company for the community management
Support (also financial) from institutions

Q15. *Would you find an App useful to manage and monitor your production quota?*
Y/N/Partly

Q16. *What features would you like this App to have? (more than one answer possible)*
User friendly consumption and production statistics
Detailed consumption and production statistics
Periodic economic savings indications
Consumption/savings rankings among community members
System health
Indications/suggestions on how and when is better to consume energy (e.g. use of washing machine at the best time of day)