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BLOCKCHAIN AS A NEW TECHNOLOGY IN RENEWABLE ENERGY COMMUNITIES

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INDEX

ACRONYM TABLE

c.c.	Civil Code
CEC	Citizen Energy Community
ComESto	Community Energy Storage: Aggregate Management of Energy Storage Systems in Power Cloud
CSP	Concentrating Solar Power
dapp	decentralised application
ENEA	Italian National Agency for New Technologies, Energy and Sustainable Economic Development
eNeuron	greeN EnergyHUbs for Local IntegRated Energy cOmmunities OptimisatioN
ES	Energy Storage
GDP	Gross Domestic Product
GECO	Green Economy COmmunity
GSE	Gestore dei Servizi Energetici
GWh	Gigawatt-hours
ICOs	Initial Coin Offerings
IEA	International Energy Agency
KWh	Kilowatt-hours
LV	Low Voltage
MV	Medium Voltage
MWh	Megawatt-hours
NRPR	National Recovery and Resilience Plan
PNIEC	Piano Nazionale Energia e Clima
PODs	Point of Delivery
PON	Programma Operativo Nazionale
Powr	Power Ledger Token

P2P	Peer-to-peer
REC	Renewable Energy Community
RES	Renewable Energy Sources

TABLE OF FIGURES

INTRODUCTION

This thesis aims to provide an overview of the use of blockchain in the energy field and, specifically, as a tool for managing the exchange activities of the energy communities. The issue calls into question the population growth and the aspiration of developing countries to achieve similar economic standards to those of industrialized countries. These aspects explain the unstoppable increase in energy demand, which, while it has led to growth in Gross Domestic Product (GDP) and employment, is producing increasingly devastating environmental consequences (Zannini 2020). The 'greenhouse effect', which has resulted in a planet-wide rise in temperature, testifies to the extent of this. The picture described poses two problems: on the one hand, there is a need to sustain growth and meet energy demand from an economic point of view; on the other, new solutions are needed to reduce risks associated with environmental impacts. This is the greatest challenge of our century, which can only be met through the efficiency of energy systems, the reduction of hydrocarbon consumption and the use of sources with low or no environmental impact, such as 'renewables' that are characterized by being able to reproduce themselves spontaneously.

Although the main source of available energy is the sun, which converts the hydrogen atom, of which it is composed, into light and radiation, at present, in the world energy mix, oil, coal and natural gas weigh, still, more than 81%, because the plants were designed to be used with fossil-derived energy (International Energy Agency 2020). In just over a century, energy consumption has grown 13 times and, according to the International Energy Agency (IEA), this increase is expected to continue in the coming decades (International Energy Agency 2020). The problem that needs to be highlighted is that oil, gas and coal came about under specific geological conditions that are not so easily repeated, especially not in timescales compatible with current rates of withdrawal. Moreover, as stated on the aforementioned IEA report, energy demand is expected to increase by 50% between now and 2030 (developing countries will be responsible for 70% of this increase, and among them, China alone for 30%)[1]. So far,

[1] In November 2020, *the International Energy Agency's forecast in the Renewables 2020 report, which tracks the current state of the art of solar, wind, and hydroelectric and projects it over the next five years, predicts that renewables will surpass fossil fuels.*

the results of global commitments to change the development model (less consumption by advanced countries and more equitable distribution of resources to others) have not borne substantial fruit, and as far as fuel resources are concerned, there are those who predict that oil will run out in 70 years (International Energy Agency 2020). For all that has been said, it seems clear that all non-renewable resources will soon reach a "peak," that is, a time when production will no longer be able to keep up with demand (International Energy Agency 2020). In addition, inexorably, they will begin to decline, given that extraction will be increasingly difficult, less economically advantageous and environmentally impactful. Therefore, it becomes imperative to question the impacts that the *habitat* is undergoing, given that the use of fossil fuels produces carbon dioxide (CO_2), which, when released into the atmosphere, increases the natural 'greenhouse effect' on Earth, expanding the environmental heat flux responsible for climate alteration and consequent global warming (International Energy Agency 2020). The solution to the described energy and environmental problems could be the use of a set of innovative technologies, and most of this solution is certainly related to renewable energies, those sources based on the great forces or natural cycles that ensure, year after year, new energies that present themselves as virtually inexhaustible. Furthermore, such sources do not pollute, helping to reduce impacts on health and organic life on the earth. It is possible to distinguish between traditional renewable sources, which are characterized by their widespread and intensive exploitation (e.g. energy produced by hydroelectric power plants) from non-traditional renewable sources whose exploitation is still not widespread (e.g. energy produced by a wind power plant or photovoltaics). According to the definition that can be drawn from Law n. 10 of January 9, 1991[2], the following are considered renewable sources of energy: *"the sun, wind, hydraulic energy, geothermal resources, wave motion and the transformation of organic and inorganic waste or plant products".* The following are instead considered to be energy sources *assimilated to renewables*: cogeneration (combined production of electrical or mechanical energy and heat), recoverable heat from exhaust fumes and from thermal, electrical and industrial process plants, and other forms of recoverable energy in processes, plants and products,

[2] Regulations for the implementation of the National Energy Plan on the rational use of energy, energy conservation and the development of renewable energy sources. Law No. 10 of January 9, 1991 was finally replaced by Interministerial Decree No. 37 of January 22, 2008.

including energy savings achievable in the air conditioning and lighting of buildings with interventions in the building envelope and plants[3]. The adjective "renewable" has come into common usage, but in reality nothing is renewed since, according to the first principle of thermodynamics, energy is neither created nor destroyed, in this view even fossil fuels could be considered "renewable" as long as we limit their use to the amount that the earth can produce in our lifetime. If we consider that it takes at least a million years to generate, that we are 8 billion people, and that all that the earth has accumulated in past eras is about 1500 billion equivalent tons, we should limit our consumption to about 250 grams per year[4]. The problem is then, the renewal time and the determined environmental impact. The attention to this issue by policy makers is evident both in having made increasingly cost-effective renewable solutions and in having regulated new architectures of self-generated energy consumption and exchange: The *Renewable Energy Communities*, the subject of this thesis.

In the search for solutions aimed at this end, innovative supply systems, capable of taking centrality away from supply companies and assigning it directly to consumers have been prepared. The novelty of the new system lies in the empowerment of consumers, achieved by inducing them to move away from fossil-based energy sources, making it advantageous to move, progressively, toward an integrated energy system, which made use of low-carbon sources, without neglecting the safety and reliability of the distribution network. The idea of adopting the new energy distribution systems came to life in the political design of the EU, which proposed "green" purposes including through the creation of new instruments dedicated to these goals.

In 2018 the European Union released the Renewable Energy Directive (RED II), giving legal status to Renewable Energy Communities (REC), defining a governance model and allowing energy sharing within REC. RED II facilitates REC development and investments in the clean energy transition and allows citizens to derive benefits from their participation in REC by increasing energy efficiency and reducing energy costs. In addition, by supporting citizen participation, energy communities can help providing flexibility to the electricity system through demand-response and storage, contributing to a more decarbonised energy system.

[3] L. No. 10, January 9, 1991.

[4] Data published in the OCSE website, November 2022

A key role for the functioning of REC is played by Blockchain technology, which is already making very interesting contributions and is believed to be able, in the future, to solve many open issues. Blockchain technology is a platform that makes use of a computing process through which some parties share resources (data) in order to make a virtual database, usually public, sometimes private, available to the user community for different purposes (Le at al 2021). From a content point of view, blockchain presents itself as a "ledger" in which the transactions made by the network are stored, proposing itself as a 'single collection center' as well as a 'shared' one, capable of ensuring transparency and preventing falsification of the transactions that have taken place, as well as making secure payments. Blockchain technology lends itself to be used in various areas, being a versatile ledger that allows for exchanges of all kinds through the use of specific currencies, the cryptocurrencies, whose operation is based on cryptography, or 'hidden scripts' (Berryhill et al. 2018), methods intended to make the message unintelligible to unauthorized people, thus guaranteeing, the confidentiality and privacy requirements typical of data security. Among the most widely used cryptocurrencies for regulating blockchain trading are bitcoins, the first ones introduced in chronological order. The functions that can be executed by the blockchain are increasingly expanding, to the extent that it is believed that it can be considered the platform that, in the future, will enable the performance of all exchange-based activities (Juszczyk et al. 2022). The blockchain is part of an ever-evolving set of activities identified as the "*Internet of Value*", which are systems that make it possible to carry out exchanges of value via the network[5]. Technically, the *Internet of Value* consists of "nodes"[6] that transfers value through a system of algorithms and cryptographic rules by requiring constant consensus on changes to be made to the ledger that stores every trace of digital asset transfers. Nowadays, there are two types of platforms implementing the development of blockchain solutions: *permissionless and permissioned*. In *permissionless blockchains*, anyone can participate in the transaction validation process by becoming a "node" in the network himself: Bitcoin

[5] From a computer science perspective, we adopt bruteforce, a solving algorithm that involves checking all possible solutions until the correct one is found.
[6] A "node" is said to be any device that connects to the interface of a blockchain.

and Ethereum are based on this model[7]. On the other hand, *permissioned blockchain* guarantees access to the network only to a few authorized participants and provides a transaction validation process reserved for a bounded group of actors[8]. Although marginal, there are also 'hybrid' models in the platform landscape, such as "Ripple", a solution that allows anyone to participate in the network, but only some authorized actors can take action to validate transactions. The *blockchain* most widely used today is the one that makes use of *bitcoins,* Bitcoin's trading volume on exchanges during the first quarter of 2022 decreased by 60% globally compared to 2021, but this was attributable to the general braking of exchanges related to the post-pandemic crisis. In the first quarter of 2022 it was a total of $2,420 billion, while in the first quarter of 2021 it was as high as $6,020 billion (Bluerating 2021). Such blockchain holds 4 functionalities: validation of transactions made, collecting of transactions in blocks and with verification of correctness, and lastly, the publicity of validated transactions. This platform only accepts bitcoins to settle the payments that follow exchanges, and guarantees the memory retention of the entire historical archive of the carried out transactions by associating them with the respective users who carried them out, identified by their cryptographic key. Configured as such, this system guarantees exceptionally secure, transparent and efficient exchanges. These requirements explain the accelerating spread of *blockchain*. One of the most important aspects, from a technical point of view, lies in the fact that each transaction is legitimized by a decentralized network since there is no central authority. The *blockchain* system, in addition to ensuring the complete traceability (including backward) of transactions, makes it difficult, compared to traditional electronic means of payment, to identify the parties who initiated them (so-called *pseudo-anonymity*) (Bao et al. 2020; Juszczyk et al. 2022). The object of tracking, indeed, are the activities carried out by the owners of the *wallets* (the cryptocurrency wallet) and not the identities of the actors that remain hidden behind the cryptography. These transactions can have legal relevance, being documented with the issuance of *smart contracts* that, following the transfer of currency (if they are economic transactions) attest to the new ownership (recognized

[7] There are more than 900 platforms that operate in similar but not identical ways and employ their own cryptocurrency.
[8] The *Corda* and *Hyperledger* platforms fall under this classification.

by the platform) or, in any case, to the fact that payment has been made. As for Italy, in February 2019, the conversion law of the simplification decree-law No. 135/2018 formulated a definition of Smart Contract by placing discriminants between those that aspire to legal value and those that cannot hold it. The certainty and transparency of the exchanges, combined with the unchangeability of the data, assures them a legally unobjectionable nature which explains why, in the future, it is expected that the *blockchain* may become the virtual marketplace in which everyone will be able to carry out their activities, not necessarily economic, being able to act as a versatile content sphere. Specifically, it is presumed that *blockchain* can serve as a platform in the following areas (Finck 2019): public deeds; private deeds; other semi-public deeds; financial instruments, deeds and templates; title deeds on tangible assets; title deeds on intangible assets; private equity transactions; business register; public motor vehicle register; certified wills; miscellaneous reservations; sim cards; public equities; bonds database third-party deposits; derivatives (*futures, forwards, swaps,* etc.); passport issuance; health records; deposit box; royalties; shipment delivery; crowdfunding; microfinance; microcharity[9]. Blockchain also lends itself to providing the tools to carry out energy exchanges, a market that is evolving not only in the mode of delivery but also in the structure of sources. As will be seen in the following pages this technology is engaging energy utilities by enabling tamper-proof, secure and transparent energy exchanges. In renewable energy communities in particular, blockchain is taking on the important role of a functional tool for the realization of energy exchanges, a kind of marketplace that provides efficiency and resilience. Blockchain technology is an answer, then, to the needs to exchange energy in the absence of a referent to feed it into the grid, one-sidedly, as is the case with traditional utilities. The blockchain makes use of databases that allow flows to pass through, recording them, and tracking their transactions. Due to the requirements of the platform, no monitoring is necessary by deferring to available "registries" any burden related to the reporting of exchanges.

The following work explores and clarifies these aspects. The first part is devoted to a description of the regulatory interventions that have urged energy efficiency, in particular, in the form of the use of renewable energy and the spread of Renewable

[9] Limited to the use of the blockchain as instrumental in the use of bitcoin, it lends itself, primarily, as a fundraising ledger (e.g. in Initial Coin Offerings- ICOs).

Energy Communities that are part of an innovative design that refers to energy empowerment. The recent regulation demonstrates the institutional interest in the topic. Thereafter, the role of blockchain in the architecture of Renewable Energy Communities will be analyzed, highlighting its advantages and implications. Alongside the advantages will be described the legal issues related to Renewable Energy Communities that refer to the difficulty encountered in assigning responsibilities to actors. Finally, the concrete results achieved by the first Communities and the criticalities that emerged will be described.

LITERATURE REVIEW

Renewable energies constitute a much-discussed topic in recent decades, revived in current times as a result of the difficulties in finding traditional sources from Russia caused by the current conflict. The issue has involved world politics, which, on several occasions, has tried to find common solutions aimed at directing consumption activities and, above all, production activities, toward the use of energies that do not compromise future generations and minimize air pollution.
The following pages describe the main contributions offered by the literature on the topic while also paying attention to the role of blockchain in the management of energy production and delivery. In particular, we will focus on the creation of Energy Communities and the use of the blockchain platform within them.

Methods

There are various existing reviews on energy communities. Lowitzsch et al. discuss the opportunities and challenges of the Renewable Energy Communities under the 2019 European Clean Energy Package and give recommendations for transposing

European rules into national laws. Bao et al reviewed the potential applications of blockchain technology in the renewable energy market the benefits of peer-to-peer energy sharing to both prosumers and the grid as well as a number of potential challenges facing by the energy communities, such as the co-existence of different stakeholders, regulatory and privacy issues. is hampered by various obstacles on its way to being widely implemented within the renewable energy sector. Our interviewees determined the following most challenging bottlenecks: Juszczyk et al discuss the potential benefits and challenges associated with blockchain utilisation and identify the most challenging obstacles to its wide diffusion in the renewable energy industry: lack of regulatory and legal compliance, global standardisation issues, infrastructural transformation challenges, or blockchain's trust and reputation problems. Alharby et al. discuss the issues within the blockchain based smart contracts.

Related surveys on Energy Communities and Blockchain

Year	Author	Contribution
2017	Alharby et al	Identifies four issues in blockchain based smart contracts: codifying, security, privacy and performance.
2020	Lowitzsch et al	Put the Renewable Energy Communities within the European Union regulation framework.
2020	Bao et al	Describe the potential applications of blockchain in the renewable energy market.

2022	Jusxcxyk et al	Describe the potential applications of blockchain in the renewable energy industry including its role in fostering a circular economy.

This paper attempts to give an updated picture of the state-of-the-art of blockchain application to the renewable energy communities. The main contributions of this work are as follows:

1. Description of Renewable Energy Communities and their role as flexible energy systems and as a tool for decarbonisation and circular economy.

2. Discussion of how the recognition of Renewable Energy Communities as legal entity at European level has been transposed into Italian legislation.

3. Description of how blockchain technology may help support the development and functioning of the Renewable Energy Communities

4. Description of the most challenging issues of blockchain application to Renewable Energy Communities and possible solutions.

Renewable energy communities

European policy, demonstrating sensitivity to the issue, has been distinguished in recent decades by a determined commitment to the upgrading of energy sources.
As of today, the EU targets, ending in 2030, include (compared to the data collected in 1990) a 40 percent reduction in greenhouse gas emissions, 32.5 percent reduction in energy consumption, achievement of the target of penetration of renewable energy sources in total energy consumption equal to 32 percent of the total (European Commission 2020). The bet on the future is based, therefore, on the spread of renewable energies that, unlike traditional ones, have the advantage of not releasing pollutants and of being "sustainable" in that they do not compromise the use of energy resources for future generations since they are renewable sources, such as solar radiation, wind, biomass, tides, sea currents, geothermal energy and precipitation.

The figure below, shows the breakdown of renewable sources used in EU countries in 2020 highlighting the prevalence of the use of wind sources.

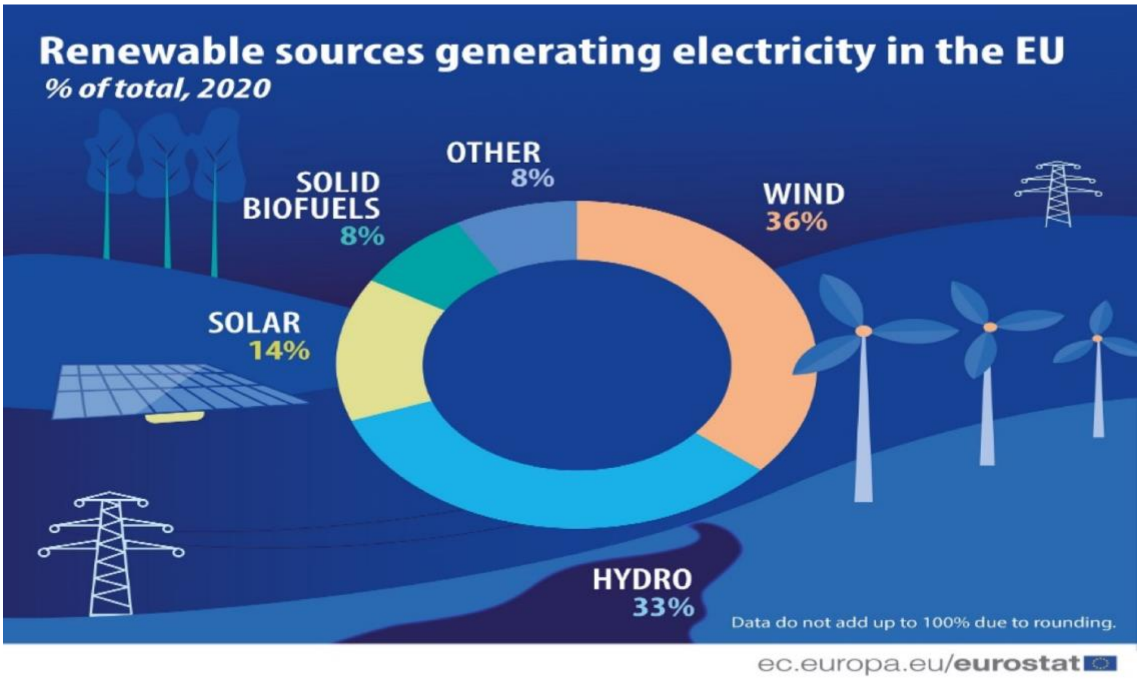

Figure 1 Renewable sources generating electricity in the EU (% of total, 2020)

Source: Eurostat (2020)

The goals pursued by the EU have the more ambitious goal of achieving energy efficiency, understood as obtaining high amounts of energy while using the least amount of resources.

Specifically, with the program launched on November 30, 2016, *Clean Energy Package for all Europeans*, instruments aimed at the dissemination of energy efficiency measures through the adoption of renewable sources, a reorganisation of the electricity market and mechanisms to ensure security of supply were introduced.

Finally, among the new features introduced by the *Clean Energy Package*, it is worth noting that a Energy Community can be defined as such based on two models: the *Citizen Energy Community* (CEC), or the citizen-producer-consumer community, and the *Renewable Energy Community* (REC), the renewable energy-based communities. The framework for CEC can be found in Directive 2019/944/EU (EMD II) (European Commission 2019) dealing with the internal market for electricity, while that for REC can be found in Directive 2018/2001/EU (RED II) (European Commission 2018).

An energy community is an association of citizens, businesses, local government or small and medium-sized enterprises who decide to join together with the aim of equipping themselves with facilities for the production, self-consumption and sharing of energy generated from renewable sources. Communities allow the performance, in a collective mode, of the activities of production, distribution, supply, consumption, sharing, storage and sale of self-produced energy (Nykyri 2022).

In technical terms, the Renewable Energy Community produces energy through one or more plants based on renewable sources, installed in the vicinity of the utilities themselves by allocating it to meet the needs of its participants (selling any excess to the supplier). Thus, the REC achieves the goal of promoting the deployment of renewable energy at the local level, through benefits related to energy efficiency, facilitating supply and making the solution cost-effective. The efficiency pursued is based on the spread of "environmental" benefits (inherent in the reduction of emissions), "economic" benefits (retraceable from the savings generated) and "social" benefits (as communities realize primarily local benefits). Unlike CEC, the REC solution concerns, only, Communities based on the use of renewable energy to which a conversion into different energy carriers follows: electricity, thermal energy and cooling energy (Lowitzch et al. 2020).

Other differences between the two Communities, on which we will not dwell, concern the organizational model, participation and control as well as the area of application. In Italy, the 2020 *Piano Nazionale Energia e Clima (PNIEC)* (Ministero dello Sviluppo Economico 2020) regulated the critical aspects of Communities REC related to self-consumption, identifying the citizen and small and medium-sized enterprises, the key players in the transformation of the renewable energy deployment system. The transposition of the RED II Directive, took place in 2021[10] but, in Italy, the process of introducing Energy Communities actually started with the *Milleproroghe* decree-law of 2020 (Gazzetta Ufficiale della Repubblica Italiana 2021).

[10] On November 30, 2021, Legislative Decree No. 199 of November 8, 2021 implementing Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (so-called Red II Decree) was published in OJ No. 285.

The structure of energy communities

From a technical point of view, Energy Communities, in a generic sense, constitute an integrated production-network-storage system that aims to meet the needs of its members through self-produced and distributed energy with the support of various types of storage systems. The latter are technologies that act as storage for the energy produced in order to distribute it when required.

Every energy distribution network needs a storage system to store what is produced and offered for sale only when there is demand (Sandia National Laboratories 2018). Storage solves the problem of having constant sources of energy and is necessary because its production is subject to continuous variations in time and place. Storage consists of a number of techniques and processes that vary depending on the form of energy being stored.

An example of Energy Storage (ES) already employed in ancient times is the control of waterways aimed at driving mills designed to process grain or motorize machinery. To ensure the presence of energy sources, complex systems of reservoirs and dams were built that stored and released water (and the potential energy it contains) only when needed. Today, the main ES tool is "stacks", placed at points where flows are created to discharge when there is a need, that is, when the energy fed into the grid is not enough to meet demand.

The problem solved by ES is not only related to the need to secure potential energy but also to create a stable energy flow, think of the case of renewable energy that needs to be stored precisely because its production is not constant. For example, in order to operate wind energy, it is necessary for the wind to be constant but it is, by nature, intermittent, so that some form of storage is necessary for the very functionality of the delivery system. Solar power is also ineffective on cloudy days, i.e., it does not achieve its purpose of providing the energy needed by the utility[11].

Photovoltaics, for example, in its Concentrating Solar Power (CSP) form is a form of Energy Storage (ES) using technology that makes use of solar panels that are installed on homes, on the roofs of industrial depots, or on boats. In summary, ES is the system of

[11] Different from effectiveness is energy efficiency, which involves adopting systems to achieve the same result using less energy.

collecting energy at times when it is available in order to deliver it when needed. Obviously, storage is realized at times when there is a surplus of energy over consumption. The forms in which ES can be realized differ depending on the energy being collected. In fact, from a technical point of view, potential energy storage, in addition to batteries, can be achieved in various ways, each adapted to the specific form of collection, its characteristics and properties. The need to make use of different ES tools stems from the versatility with which energy occurs in nature and the conditions that transform an energy 'potential' into energy. Renewable energy is present in the rays of the sun, or in the form of 'gravitational potential' of water, in the wind, etc., and, its retention, is essential for subsequent delivery.

Storage technologies today also differ from each other in their ability to provide short-term or longer-term energy storage.

The network that makes it possible for RECs to operate is called a smart grid because, in electronic-digital mode it rationalizes energy distribution among users, minimizing overloads and variations in electric voltage around the nominal value. In electrical and telecommunications engineering, a smart grid is the integration of an information network and electrical distribution network, which enables operational management in a smart, or efficient, mode. From a structural point of view, the smart grid does not replace the traditional one, but coexists with it, constituting an integration that makes energy flows that, in Communities, are circumscribed to a defined catchment area more efficient (Hejazi et al. 2018).

Such a grid makes it possible to modulate the flow of energy based on its generation and the demand that arrives in real time: this is a feature, which makes it possible to avoid voltage drops or blackouts, and is made possible by the continuous exchange of information - wired and wireless - between the grid and its participants (Van Leeuwen 2020).

In RECs, smart grids make possible the spread and coordination of distributed sources of "renewable energy" through a complete decentralization of relationships between operators, facilitating the spread of the sharing economy. In Italy, ENEA's Energy Technologies and Renewable Sources Department constitutes the national reference of Communities having gained, in the past, expertise on the development of tools and methodologies to create a smart and interactive energy ecosystem. ENEA's model distinguishes 3 different energy community user profiles: residential, tertiary, small business, suggesting different solutions aimed at modulating digitization and collaborative economy, drawn from best practices at the international level. ENEA, moreover, provides actors participating in the Community with various services and operational tools aimed at creating a "smart" energy ecosystem capable of interacting[12] with the energy distribution network.

Legal aspects of RECs. Legislative Decree 199/2021

The creation of a REC is accomplished through three steps:

1. creation of a legal entity representing the future members of the community (individuals, small or medium-sized enterprises, territorial entities, local public administrations);
2. identification of the area in which to install the production plant (or plants), which must be located in the vicinity of the consumers themselves (it is not necessary that the plant be owned by the community; it can be made available by only one of the participating members or more than one, if not even by a third party);
3. installation by each member of the community of a smart meter, i.e., a smart meter that is able to capture real-time information on energy production, self-consumption, release and withdrawal from the grid. In order to carry out their activities, communities need a platform where self-generated energy flows, in the form of supply, meeting demand and carrying out the exchange on accepted terms and made, subsequently, traceable[13].

As anticipated, the transposition of the Red II Directive took place in Italy with Legislative Decree No. 199 of November 8, 2021, which came into force the following December 15. The decree fully implemented EU Directive 2018/2001 (European Commission 2018), which, with a view to promoting the use of energy from Renewable Sources, introduced REC "energy communities." It amended and supplemented what had

[12] These include evaluating scenarios related to interactions between individual users, the community, and energy managers.

[13] Blockchain technology and smart contracts, as discussed below, realize these needs.

already been established by Law 8/2020, which had partially transposed the directive, regulating generic energy communities (De Maio 2020). Decree 199/2021 aimed to facilitate the deployment of energy communities, allowing, for example, the construction of larger and more powerful plants than under previous measures (which had a maximum power limit of 200 kW) by allowing up to 1 MegaWatt of power.

In addition, while in the past, energy communities could only connect to secondary substations, which could meet the needs of only one neighborhood, under the new decree they have been given the option of accessing a primary substation, which allows more utilities to join, even encompassing more municipalities. Finally, an incentive for local government involvement has been introduced, particularly to municipalities with a population of less than 5,000-a target that will also be encouraged by investments funded by the National Recovery and Resilience Plan (NRPR), which has allocated 2.2 billion euros for energy communities. From a participatory point of view, an energy community, therefore, could consist of both household and business users and also include municipal and local authorities. Renewable Energy Communities have been framed for all intents and purposes as legal entities recognized by the legal system/jurisdiction (ordinamento) to exercise rights and be subject to obligations, and can be established in any form (cooperative, consortium, association, partnership, nonprofit organization, benefit corporation). The decree envisioned both "Renewable Energy Communities" and "Collective Self-Consumption Communities," two different configurations of energy communities that have the same goals though, in different modes. A Self-Consumption Group represents a collection of at least two self-consumers of renewable energy acting collectively under a private agreement and located in the same condominium or building. The decree clarifies that the Renewable Energy Community (REC), is, on the other hand, a legal entity composed of utilities that refer to the same low-voltage grid, holding a single MV/LV transformer substation and sharing electricity produced by one or more RES (Renewable Energy Sources) plants.

This form is suitable for utilities represented by cottages and buildings (as anticipated, including municipal or belonging to Small and Medium Enterprises) that, given their size, employ energy from renewable sources using a single shared MV/LV substation.

Unlike the REC, in a Collective Self-Consumption configuration, the generating facilities are always located in the area close to the building or apartment building. These are more collected realities, the classic example of which are cottages located in the same neighborhood, which could have a photovoltaic system that uses the energy produced by allocating it, first and foremost, for self-consumption in order to give the excess energy back to the community.

The decree has provided incentives for investments to build the plants, while, the current remunerations of the GSE (Gestore dei Servizi Energetici) to which the community will refer, are to be divided among all participants.

To date, the spread of energy communities (in their various forms) sees Italy lagging behind; the figure below shows the gap with other countries.

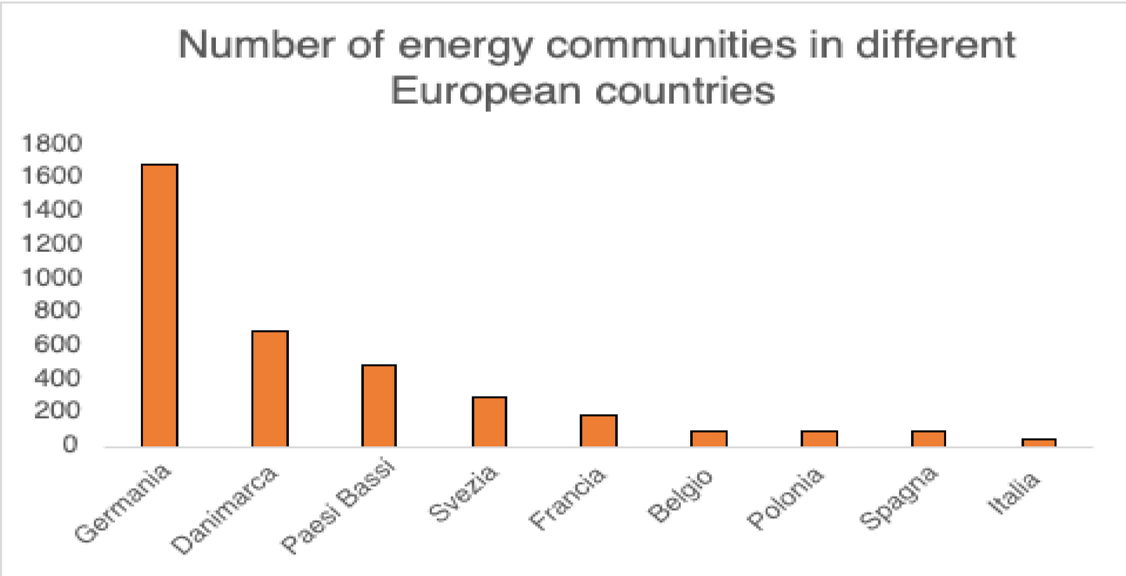

Figure 2 Number of energy communities in different European countries

Source: OTOVO (2020)

Italy also ranks after the leading countries in the use of renewable resources. Looking at 2020 figures, Italy ranks in the average of EU countries but after the most advanced economies.

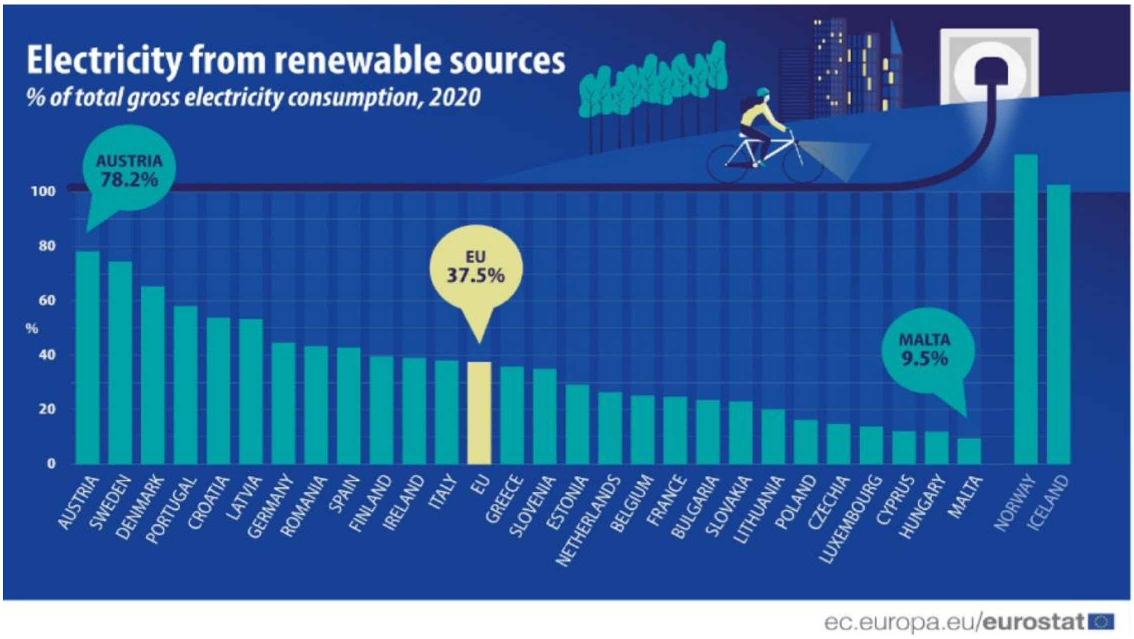

Figure 3 Electricity from renewable sources (% of total gross electricity consumption, 2020)

Source: Eurostat (2020)

According to Enea's guide to energy communities, by 2050 some 264 million European citizens will become prosumers, with the ability to generate up to 45 percent of electricity from renewable sources and achieve climate neutrality through active consumer participation. The development of RECs is also strongly linked to the deployment in the industry of blockchain, the platform that enables trading of a versatile nature, ensuring its efficiency and traceability.

BLOCKCHAIN TECHNOLOGY

What is a blockchain

From a technical point of view, RECs need a mechanism that integrates the smart grid, combining technical instances with negotiation instances, i.e., relationships between participants.

The blockchain is a platform that can realize the matching of supply and demand for self-generated energy from the REC by being able to activate tools that optimize exchanges between multi-carrier energy hubs (electricity, gas, thermal energy, etc.).

In addition to ensuring that the described storage runs smoothly, the blockchain system records the available quantities of energy, the demand, the "node" of origin, and triggers its transmission in the reported direction. Every exchange becomes recorded and traceable.

The blockchain is a platform that is breaking into many activities, offering an exchange and payment service, which operates digitally and, in the regulation of trading, uses cryptocurrencies, e.g. ethereum, bitcoins and others. It takes the form of an architecture that makes possible negotiations, monetary exchanges, and the issuance of smart contracts, which prove their contents, all in a traceable and highly reliable way based on commands that are activated only when validated.

Blockchain also enables complete backward traceability of all transactions making it functional for any reconstruction needed to trace back the trades made.

The Blockchain holds a ledger that stores all the movements made by the network, since the birth of bitcoin, and stands as a 'one-stop' and 'shared' hub that can ensure transparency and the non-falsifiability of payments. Blockchain technology enables a Cryptocurrency Payment System, (there is no monopoly of the bitcoin cryptocurrency, but the manner of its use make it unique in just such a contest).

Blockchain thus fits into an increasingly complex and evolving set of activities that can be called the "Internet of Value," represented by those systems that make it possible to exchange value over the Internet (as easily as information is exchanged today) (Ron 2014).

Technically, the Internet of Value is the digital network of nodes that transfer value using a system of algorithms and cryptographic rules. It is based on reaching consensus on changes to the ledger that tracks digital asset transfers. There are several platforms that enable the development of Blockchain solutions and they can be categorized within two major groups: permissionless and permissioned (the two will be discussed in more detail below). The Blockchain has 4 functions: it detects transactions, enables the creation of the blockchain and its verification of trustworthiness, and, finally, makes validated transactions public.

Once the 4 functions are activated, the Blockchain stores the entire historical archive containing all transactions, associating them with the respective users who executed them. Thus configured, this system guarantees exceptionally secure, transparent and efficient exchanges (Colette 2021). Indeed, blockchain makes it possible to identify the owners of the wallets and their transactions only if the users turn to a specialized company that manages the bitcoin wallet on their behalf and if this company is regulated. This does not happen if the user "downloads the app" from the Internet and manages the wallet themselves, that is, if he buys the "virtual currency" directly from a miner or performs the mining activity[14]. The validation of the various transactions recorded in a Blockchain is followed by so-called miners, people who contribute, through their computing power, to the control and verification of the blocks. Miners must come up with a cryptographic solution concerning the block, representing a code that is consistent with all transactions (credit and debit) stored by the Blockchain[15].

In other words, the cryptographic solution must satisfy all the equivalences of the individual block, so that all the exchanges balance the parameters declared as credit with those declared as debit.

The 'system' is set up to alert about the correctness of the result and allows the miner to announce it to the rest of the network.

Subsequently, the various miners will receive the new updated block, verify it, and add it to their chain.

Technically, then, the activity of a miner consists of finding a hash (which maps a string of arbitrary length to one of predefined length).

What are smart contracts

Smart contracts[16] are programmable transactions to attest new ownership or, at any rate, payment.

The spread of blockchain has required a series of adjustments, including legal ones, to make it fully functional. One of these is the smart contract, which in Italy has seen its formal recognition in Article 8 ter of the so-called Simplification Decree (D.L. 14

[14] In this case, tracking of subjects would only be possible through postal police investigations of associated IP addresses.

[15] From a computer science perspective, it is a problem that cannot be solved in any other way than by bruteforce, a solving algorithm that involves checking all possible solutions until the correct one is found.

[16] Smart contracts are represented by computer protocols that verify the negotiation or execution of a contract, sometimes allowing partial or complete exclusion of a contract clause. Smart contracts usually also have a user interface and often simulate the logic of contract clauses.

December 2018, No. 135, converted into law with L. 11 February 2019, No. 122). This discipline shows that the legislator has recognized that the smart contract could be proposed, in the future, as an elective instrument for the circulation of wealth.[17] (Gitti 2019; Gitti 2020). Article 8, co. 2 of L. 122 cited. outlines the "smart contract" as a computer program that uses technologies based on distributed registers and whose execution binds two or more parties automatically on the basis of effects predefined by them.

In Italy, "smart contracts" meet the requirement of the written form required for transactions, provided that the parties involved are identified electronically, using a process whose requirements are set by the Agency for Digital Italy (AgID)[18].

Despite the intervention of the legislator, there are still some uncertainties about the real scope of smart contracts, admitting in theory also the use of traditional non-strictly centralized databases that exceed the limits established by permissioned systems; and especially if, and under what conditions, the smart contract can be considered a real contract ex art. 1321 of the Italian civil code. Similar doubts also come from the work of common law jurists, where, in view of a traditional approach more oriented to the economic analysis of interests than to dogmatic categorization, the questions about the nature of the smart contract have not found an answer (Cuccuru 2017).

From a technical point of view, the smart contract operates following a precise deterministic logical schema of the type "if this then that": once concrete conditions have been met, the algorithm gives the consequent instruction, performing the specific operation that reflects the fulfilment of the predetermined conditions.

For example, if X pays Y the amount indicated in the algorithm, the smart contract, receiving instruction that Y's property titles are adequate, processes the assignment of new ownership. This is possible because the information that the smart contract must retrieve is provided by oracles, that is, software independent from the blockchain that can

[17] This possibility is hinted at by the European Union itself, which, on the topic, has already highlighted *"the need for the Commission to carry out a thorough assessment of the potential and legal implications [...] of smart contracts,"* thus the European Parliament Resolution of October 3, 2018 on "Distributed ledger technologies and blockchain: building trust through disintermediation."

[18] whose guidelines were adopted after ninety days from the date of entry into force of the law converting the decree.

monitor elements outside the blockchain belonging to reality, and then communicate them.[19].

The execution of the smart contract is not a guarantee of performance, nor does it give the right to rely on a third party (public or private) to obtain compliance with the agreement, however, the parties can rely on the architecture of the software, the immutability and the verifiability of the operation in the blockchain.

The terms of the operation are, in fact, contained in the source code of the smart contract[20],which is activated through transactions validated on the blockchain with cryptographic digital signature (Alharby et al 2017). It is clear that only a possible error in the programming of smart contracts can introduce the possibilities of executions that differ from those agreed upon.

In computer language, the term smart contract allows the above-mentioned functions, which make it more correctly qualify as a decentralized application (dapp). A dapp can be defined as a blockchain-enabled website, where the smart contract constitutes the back-end that allows to insert new transactions in the blockchain. From a legal point of view, it is clear that a smart contract and, more generally, the context of the blockchain provide functionalities with a high impact on changes in rights.

It is a tool that could replace the contract, allowing the exercise of private autonomy by considering the smart contract a "pure exchange dynamics" (Rossi 2018).

In reality, the tool is no less involving than a contract but, while the smart contract is binding ex se, on the contrary, the traditional contract anchors its bindingness to a normative source and therefore external to the contract itself.

In addition, thanks to the singularities of the blockchain, it is able to ensure with certainty: (i) the exact date and time when it was made[21], (ii) any subsequent modification activities

[19] The oracles present "the inevitable disadvantage of reintroducing a degree of uncertainty into the system. The formalized relationship is, in fact, exposed to the risk of malfunctions or tampering of the external sources of information on which it relies" as stated by CUCCURU A., *Blockchain and contract automation. Reflections on smart contracts*, in NGCC, II, 2017, p.111.

[20] The source code consists of a sequence addressed to the electronic processor. The object code, on the other hand, is a binary code sequence of two physical states of the processor, which can, for example, coincide with the opening and closing of an electromagnetic circuit or with the polarization of a silicon device.

[21] This is done through the application of the digital timestamp during the validation of the operation on the blockchain.

that the parties have decided to make to the program; and, finally, it is currently being studied to ensure that (iii) the origin of the statements by the parties is found[22].

An additional characteristic is that with the smart contract, the execution of the contractual program does not depend on the persistence of the will of the parties, since it is carried out by a software within a network of computers (i.e. the blockchain) that, as repeatedly stated, is immutable and therefore removed from the availability of the parties, who in this phase no longer have any discretionary power[23].

Decentralization of the blockchain prevents any external intervention subsequent to the validation of the agreement and the level of unchangeability of the block is directly proportional to its diffusion: the more distributed it is, the more computational power will be necessary for its modification. This means that an effectively distributed blockchain will be in fact unchangeable and unattackable and this postulates that no modification can be made to the smart contract, regardless of the opportunity and legality of the same.

Also thanks to smart contract, blockchain lends itself to be used to intermediate in all areas where services are performed: Financial Instruments, Deeds and Templates; Public Deeds Private Deeds; Other Semi-Public Deeds; Securities on Tangible Assets; Securities on Intangible Assets; Private Equities; Public Motor Registry; Wills; Certifications; Reservations; SIM cards; Public Equities; Business Registry; Bonds; Databases; Deposits with third parties; Derivatives (futures, forwards, swaps); Passports Health Records; Deposit Boxes; Copyrights; Consignment Delivery; Crowdfunding; Microfinance and Microbenefits. In recent times, blockchains have become the subject of interest by the energy market because of the opportunity they offer to exchange energy in a simple manner and, most importantly, by eliminating intermediaries with obvious implications

[22] In many blockchains, and in particular, in the one that uses Bitcoin, the subjects who carry out the transactions are covered by anonymity, so the subjects who operate in them are not required to register for personal identification and instead allow the use of pseudonyms. In this regard, various projects are underway, some of which are already partially operational, such as the *IBM Blockchain Trusted Identity™.*

[23] The greater degree of certainty in the performance provided by a smart contract could have implications in e-commerce, where the traditional contract and its remedies are still inadequate. *"The risk of online fraud could be drastically reduced: since A's performance is dependent and inseparable from that of B, the execution of the terms of the agreement is ideally simultaneous, so that it would not be possible, for example, for one party to retain payment y without delivering the promised good x, or that, on the contrary, payment y could be canceled once x is obtained" as stated by CUCCURU A., Blockchain and contract automation. Reflections on smart contracts, cited, p.112.*

for service prices. In fact, through the use of blockchain aimed at certifying the purchases and sales of energy, a more streamlined market is achieved, free of intermediary costs (represented by brokers) that, traditionally, are present in the distribution chain, mediating between producers and grid operators (Gestore Mercati Elettrici 2022).
In practice, the blockchain makes it possible to regulate energy exchanges by coordinating with the network serving the community, reporting the transactions made and ascertaining their correctness.

Review of projects using blockchains in RECs

The present analysis highlights the existence of a concrete institutional commitment to the dissemination of renewable emergencies, with a view to energy efficiency.
ComESto, (Community Energy Storage: Aggregate Management of Energy Storage Systems in Power Cloud) is a project implemented under the PON 2014-2020[24] which regulated the integration of energy storage systems from renewable sources. Thus organized, the system enables the individual community member to be active consumer and prosumer, or producer-consumer, through Demand Response programs and 'smart' management.
It is precisely storage systems, which enable users to produce, use, store and 'resell', when needed, self-produced renewable energy, optimizing the management of the whole process. For this reason, there are many projects aiming at its optimization, among them, those under H2020: Innovation Action, which offers innovative digital tools to direct energy faster and with less loss to storage points and subsequent use.
The eNeuron (greeN EnergyHUbs for Local IntegRated Energy cOmmunities OptimisatioN) project also aims at the realization of integrated energy systems with high levels of penetration of Renewable Sources, integrating all energy carriers, from electricity networks with gas, heating and cooling networks, etc. It is a project that ensures the storage of all forms of energy, as well as the modernization of electric vehicles and conversion processes.

[24] This project is funded by MIUR and the EU.

Regarding Commmunities, the EU has clarified that the official management platform is being tested in four locations, located in Italy, Poland, Norway and Portugal. Co-funded by the EU's EIT-Climate Kic Program, among the ongoing projects, special prominence is also inherent in GECO (Green Economy COmmunity), which has implemented the first energy community in Italy[25].
The focus of GECO is the 'circular economy' realized through the involvement of citizens and businesses with the aim of energy-conscious use, to be achieved through sharing territorial resources, preparing actions to reduce environmental impact, and contributing to the improvement of the area involved. A special focus of the GECO project is on the process of spreading 'energy and social awareness'.
Regarding the emergence of RECs, an overview requires the assessment of their spread internationally as well as nationally.
Among the most interesting projects that are already at an advanced stage, the following are worth mentioning: Enerchain (Enerchain 2022), Power Ledger (Powerledger 2022) e Brooklyn Microgrid (Brooklin Microgrid 2022). Enerchain, created in 2016, is an experimental blockchain-based peer-to-peer energy trading system that allows platform participants to receive and place orders and formalize exchanges by storing them in a decentralized ledger. It should be noted that through this system Endesa - an Enel group company - was able to implement Spain's first blockchain-based energy exchange.
As mentioned above, the use of blockchain is a promising solution for simplifying the energy exchange system by making it faster and cheaper.
Precisely driven by such opportunities Ponton[26], a German company based in Hamburg, has developed one of the most interesting projects in the landscape of energy initiatives, involving a blockchain platform for energy exchange: Enerchain. Companies participating in the project include Enel, E-on and Engie[27].
By joining the Enerchain project, investments aimed at developing blockchain potential are shared, the main objective of which is to send, receive and place orders for energy

[25] The location of the first Italian Community has been identified in the Roveri and Pilastro areas of the city of Bologna
[26] The industry specializes in developing energy solutions.
[27] Italy's Acea also collaborated on the project.

supplies through a decentralized registry and *peer to peer*[28]*exchanges*, that is, without the intermediation of a central operator. Exchanges via blockchain are, however, already underway, Endesa, an Enel group company, has carried out the first transaction in the Iberian Peninsula.

At the base, a commercial agreement has been drawn up with Gas Natural Fenosa for a total of 5.95 GWh of natural gas, and a rapid development of the use of blockchain through the extension of smart grids is planned for the future.

Among current projects of interest is Power Ledger, an Australian company that has built a blockchain platform for buying and selling self-generated electricity from residential renewable plants.

The system allows for real-time exchanges, providing for storage and subsequent disbursement based on the digitized submission of the request and recording every transaction.

Energy exchanges are carried out with the simultaneous issuance of smart contracts that enable energy credit and debit relationships to be traced.

Concurrently with the implementation of the platform, two specially issued cryptocurrencies were created: the Power Ledger Token (Powr) and the Sparkz. The Powr is the countervalue issued for the power generated and sent to the system and can be used to acquire Sparkz, another currency that is exchanged into local currency.

The project described has been included by the Australian government in a program to create a city with minimal environmental impact, Fremantle.

Energy exchange blockchains, electric car charging stations, and rainwater recovery and treatment facilities are planned to implement the project. As these initiatives have the advantage of accelerating and economizing exchanges, they are intended to influence the city's overall storage efficiency.

Finally, with the Brooklyn Microgrid project, which began in 2016, a network between residents of the New York borough of Brooklyn has come into being: they, thanks to the smart implementation of the available electricity grid, can sell renewable energy not intended for their own consumption, or buy excess clean energy produced by prosumers. Exchanges are formalized virtually through a permissioned blockchain.

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[28] Peer-to-peer (P2P or peer/parity network) in telecommunications denotes a model of logical computer network architecture in which nodes are not only hierarchised in the form of fixed clients or servers, but also in the form of equivalent or 'peer' nodes (peers)providing no coordinating figure.

The initiatives described have influenced energy storage and can be considered the real energy challenge of the future. Indeed, the ongoing investments, both at the European and non-European level, testify to a decided interest in increasing storage capacity, thus ensuring the stability of energy supplies and its quality. In addition, the issue of electricity trading has highlighted the possibility of introducing new energy trading conditions involving the use of blockchain, also enabling the spread of Energy Communities.

Examples of Italian Energy Communities include several, including the REC "Energy City Hall" project in Magliano Alpi, in the province of Cuneo.

This is a municipal-initiated REC, which has seen the construction of two photovoltaic plants with a total capacity of 40 kW, serving, via a smart grid, both public and private buildings.

The Energy Center of the Polytechnic University of Turin collaborated on the project. In addition, the municipality provided smart meters, that allow obtaining timely consumption data regarding electricity, connected to all PODs (Point of Delivery), or point of supply, adhering to the REC, and the Energy4Com platform has been chosen to enable energy production and consumption flows.

Italy's first plants appear to show that the objectives pursued are being achieved, in particular, in the form of:

· environmental benefits: energy from fossil fuels is avoided and the use of pollutants and climate-altering agents is reduced.

· lower bills: as the more energy is self-consumed, the lower the costs of the variable components of the bill. In fact, each member of the preserve contracts with his or her electricity supplier, to whom he or she regularly pays the bill; in return, he or she receives a benefit-sharing amount from his or her community. Thus, if one puts a certain amount of KW into the grid, that amount, being recorded, comes back to him in the form of savings. Since it is not taxed, such compensation is, in fact, transformed into a reduction in utility bills;

· lower costs and higher incentives (in fact, focusing on the case of Magliano Alpi, by joining a REC one has the opportunity to obtain tax deductions on the photovoltaic systems made available to the Community, which increase up to 110% if one accesses the Superbonus. In addition, the GSE (Gestore dei Servizi Energetici) applies special tariffs for 20 years on shared energy);

· Social awareness: as the principle of sharing and social responsibility is consolidated.

Economic benefits are also related to the energy fed into the grid, which can be valued through the "Dedicated Withdrawal" mechanism (which consists of making the energy produced available to the GSE) at a unit price equal to the Hourly Zonal Price.

In Magliano Alpi, shared energy benefits from an incentive of about 12 cents per kWh obtaining, overall, a remuneration of about 17 cents per kWh on the energy produced and consumed by the community.

The picture described shows the achievement of the goals pursued and convinces about the synergy between blockchain and RECs. However, much centrality is given, still, to the use of smart meters, the manual meters that indicate the respective consumption. RECs are still medium to small in size and the initiatives that see them emerge are often public which indicates a lack of true awareness of the benefits of the tool.

However, tax incentives and the good performance of the first settlements authorize very positive expectations about their diffusion.

DISCUSSION

The Advantages of using blockchain technology in RECs

The blockchain, therefore, constitutes a system of settling trades between parties capable of ensuring security to the negotiations put in place.

The main advantages are related to the storage and thus traceability of the activities carried out, to which must be added various other benefits, universally recognized, such as the accreditation of transactions carried out in the absence of a supervisor, with obvious savings.

An additional advantage of blockchain lies in its nature as a tool that nullifies any point-of-failure which implies that attacking or tampering with a single node does not result in the blocking of the entire system (unlike in systems where control is exercised exclusively by a central authority).

Blockchain technology (distributed ledgers technology) can be of two types: *Permissionless*, which implies open participation, *Permissioned*, which implies restricting participation to a few selected participants based on certain criteria.

It consistently exhibits three characteristics: *Immutability*, i.e., the inability to change the data of concluded transactions, as they are stored in the registers; the *inalterability* of data, which, in energy exchanges, realizes an important assumption that occurs when the excessive demand for flows, in automatic mode cannot be met. This because it is necessary to possess excessive computational power to coordinate the action of other nodes connected to the register in order to violate the copies of the register owned by individual nodes. It is, moreover, a *dual cryptographic key system* since it uses both public and private access in the provisions.

The public key is visible to all while the second allows access to the individual account making personal transactions enforceable.

Only when the private key meets the public key does a blockchain configuration come about that registers the new status, and this provides security.

Finally, the blockchain realizes a distributed consensus that is created when transaction validations are allowed without the intervention of a central authority.

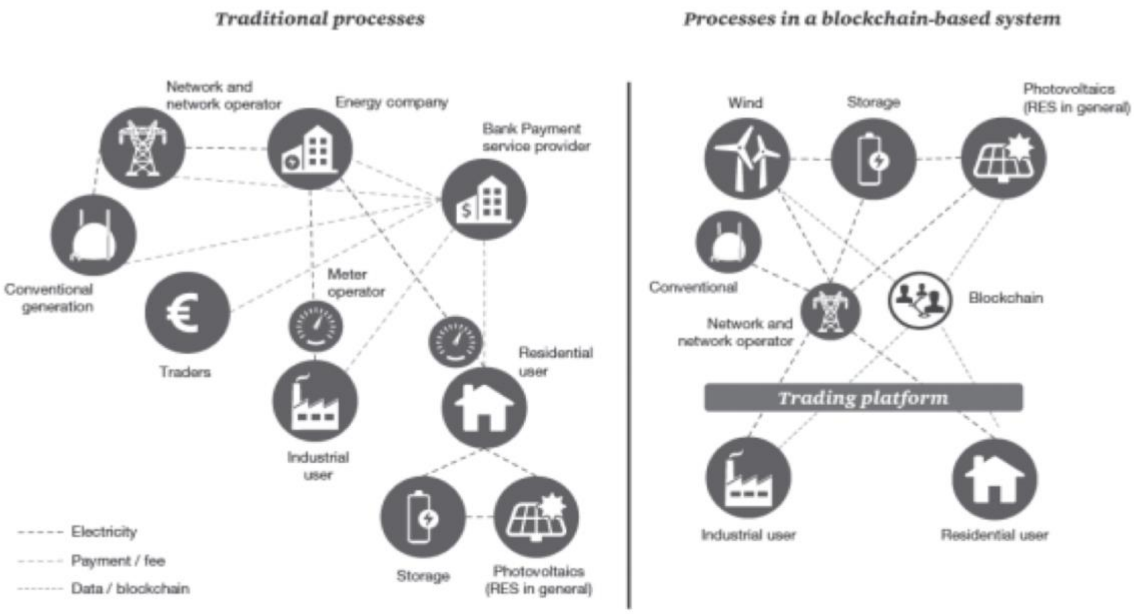
The computer protocol of a blockchain can also self-execute with the realization of "offchain," real-time events external to the platform: think of the activation of the algorithm in charge of payment that is triggered only upon delivery of a good purchased online.

It is precisely because of these advantages that the use of blockchain in energy is having major impacts and is expected to become increasingly widespread (Andonia 2019).

Currently, in the traditional market, outside of Communities, a central role is played by suppliers, who operate in the last segment of the energy chain by connecting the producer with the end consumer. These, in the exercise of their function make use of a rather complex infrastructural apparatus, in which distribution and transmission companies also play the role of controllers and maintainers. This is a management system that is perfectly compatible with a centralized production model, in which energy moves one way through the power grid covering vast distances: from a few large power plants to a large number of consumers.

Decentralization of production sources, realized by communities, aided by smart grids technology and blockchain make the described model no longer suitable to meet the efficiency needs of the energy market.

It has been noted above that the centrality of intermediaries has been replaced by the user themselves creating a more fluid and economical architecture. Thus, the figure of the provider, as the consumer contractual counterpart, appears to be unnecessary in platforms. In communities, the new network of actors (consumers, producers and prosumers) formalizes transitions within the framework of a blockchain, which operates in parallel with the physical network by communicating with it. The mechanism of communities is based on the simultaneous operation of two networks: one real and one digital, with the former connected to the latter (Zetzsche 2018). In the described architecture, we make use of blockchain technology, realizing and recording energy exchanges, giving automatic order of delivery to the nodes from which the request comes. The following figure shows the structural differences between traditional and blockchain-based exchange processes.



Source: OTOVO

Smart contracts formalize the exchanges and command the recording of all transactions in the individual registers which are the sources of communications to the physical network which is activated with the transfer of energy (Schneiders 2021).

Accountability and Liability in energy management based on blockchain technologies

In the RECs (but also in the other Communities) the mechanism described does not provide for a central authority in charge of energy supply as it is self-produced.

This aspect is the main problem in legal terms by making it difficult to allocate responsibilities (Faccioli 2005). While blockchain eliminates the involvement of third parties, creating opportunities for savings, it is also true that the existence of an intermediary provides a certain reference in case of disputes, malfunctions or interruptions in supply.

The issue of accountability arises again when considering both decentralized permissionless and permissioned registry systems.

This issue was clarified by a 2018 order in which the Supreme Court defined the position of different market players involved in energy supply: the energy supply company (in this case, it was a mere retailer) cannot "*esser chiamata a rispondere, ai sensi dell'art.1228 c.c., della relativa mancata erogazione per fatti imputabili al mancato regolare funzionamento della linea di trasmissione dell'energia e/o della struttura fisica deputata al relativo trasporto e alla conseguente distribuzione al dettaglio*"[29]. In other words, the judges ruled that if the power failure (which in the specific case had caused a blackout and damage), resulted from a "system failure," that is, mismanagement of the transmission and distribution phase, the responsible party should not be identified in the supplier (in Italy, the company Terna is responsible for managing the electricity grid). Otherwise, in the event that the interruption of energy supply is not attributable to inefficiencies concerning the distribution and transmission structure, the supplier entity shall be liable for any damages caused to the energy consumer by way of contractual liability.

The judges based their decision on a strict interpretation of Article 1228 of the Civil Code, arguing that the energy distribution company cannot be considered in the same way as an auxiliary of the supplier, since the latter would have no decision-making power with

[29] Corte di Cassazione, sez. III Civile, ordinanza n. 1581/18

regard to the awarding of the distribution assignment: the awarding of the assignment, in fact, is the essential element for the application of the cited article. However, this approach does not answer other questions, at least on the basis of two orders of reasons pertaining to the nature of the activity carried out by the subcontractor-supplier and also to the consistent difficulty of tracing the specific responsibilities in the case of malfunctioning of the system.

In the case of a "system deficiency," there is a case of irresponsibility, which would imply placing the supplier's business risk on the end customer, while its protection should be the central point in the construction of the liability system. Based on this reconstruction, "contractual liability" cannot be ruled out in the case of missing or inaccurate service delivery. The problem is particularly related to the technical complexity of the energy system, which very often makes it difficult to trace the real causes of malfunctions, or rather, makes it uncertain whether they can be attributed to a single party in the chain. The solution ensures that this uncertainty does not affect the position of the administered party.

In addition, the distributor is required to ensure a good state of maintenance of the network and to ensure the capacity of the system, however, this role of a technical nature is on a different level than the contractual obligation, assumed by the supplier, to administer the energy good (Grasselli 2011).

That said, bringing this analysis back to the Communities architecture, in outlining the accountability framework one should consider that in a highly decentralized and complex system, tracing the causes of malfunctions or errors can be a non-negligible problem, and the protection of consumers and prosumers who decide to participate in peer-to-peer energy exchange platforms may be weakened precisely because of the absence of an intermediary.

The question requires understanding how the relationships between the operators of a blockchain platform can be legally qualified, identifying a solution that can be satisfactory to the needs of users-prosumers and consumers.

Such research, in turn, requires identifying risks that can affect the quali-quantitative aspects of energy supply as well as understanding the role of "nodes," from where energy sorting orders originate, as the blockchain structure changes, since distributed ledgers systems can be classified into permissionless or permissioned.

In the first models, typical of systems adopting Bitcoin, there was the highest degree of decentralization by having no limits to participation in the blockchain. In permissioned-type blockchains, the degree of decentralization fades by being provided with an authorization mechanism, which operates both upon entry and upon completion of individual transactions.

In the latter case, the platform is not suited to support the communication required for real-time physical transactions as is the case in Energy Communities.

Moreover, although difficult and rather complex, one cannot theoretically rule out a simultaneous hacker attack on multiple "nodes" that would alter the validation process by going so far as to store different versions of the records that contradict each other.

Permissioned systems, have fewer validation "nodes," which exposes them to decrypted risk by making alterations easier. In addition, it should always be remembered that blockchain does not implement any "merit" checks on transactions, which are stored even if based on inaccurate commands. Criticism can also come from smart contracts, which do not always have the ability to express the real needs of the parties. Specifically, this happens when the constitutive phase of the contract is not accurate creating the prerequisite for later influence on the executive one. Because of what has been described, especially in permissionless systems, it is possible, though difficult, for problems of ungovernability of energy supply to spread.

In addition, the risk of smart contracts malfunctioning cannot be ruled out, which could lead to system bugs, technical anomalies that lead to errors.

Indeed, smart contracts are based on compliance standards in computer protocol programming that, if not followed to the letter, could affect the quality of performance to the point of preventing, in the most serious cases, the continuity of transactions.

The most relevant legal issues, as noted above, concern permissionless blockchains, those most consonant with RECs, in that, they are characterized by the absence of any figure to turn to in case of disputes or malfunctions (Cuccuru 2017).

Interpretive problems also concern the relationships between the "nodes" of the blockchain and the shared functions (as well as those between the various "nodes"). On the one hand, permissionless blockchain realizes perfect decentralization: only miners, who are in charge of validating transactions, through computational capabilities, guarantee the storage of transactions on the other hand, it exposes to the described

problems. Moreover, permissionless blockchain technology makes the effects of decentralization more radical while ensuring that external interventions that could disrupt its operations are not allowed, a necessary requirement for RECs.
In light of what has been described, picking up on the issue of attribution of responsibility, it should be mentioned that participants in a permissionless platform that validates energy transactions occurring in the "physical world" have no formalized legal relationship either with other participants, or with the developers of the software, or with any central control authority, which, as mentioned, is lacking.
From a digital point of view, the connection between the blockchain and the smart grid means that the user is required to download software that allows him or her to relate to the platform without other "nodes" being able to interfere. Once the computer protocol is activated, which carries out the exchange of energy, the transaction is validated by the other "nodes" and recorded on the decentralized repositories.
These steps do not involve the activation of contractual relationships, although "distributed ledger contracts" can be considered those involving the various "nodes" of the blockchain. In other words, individual "nodes" do not know their contractual counterparts but can exchange energy with each of them. The operation of the blockchain in the energy field is, in this sense, trustless with respect to the participants, the only trust is in the technology rather than in the counterparties, weakening the protection reserved for the consumer of the good "energy". Within the described framework, in RECs, distributing responsibilities becomes crucial to ensure the reliability of the system, managing to combine the benefits offered by complete decentralization with the acceptance, by all "nodes" of the blockchain, of the risk of failure of the system itself.
However, the impermeability to the outside world of permissionless blockchains can have repercussions in the context of energy transactions.
The inability to interact from the outside in the governance of a permissionless blockchain system also makes the application of traditional contractual institutions, such as nullity or termination, problematic, which reinforces the inherent difficulty in intervening in the event of dysfunction in the contractual agreement.
To sum up, while the concept of distributed responsibility can solve the problems related to the allocation of respective rights and obligations, complete decentralization, which is

necessary for communities' energy exchanges, is currently a barrier that cannot be overcome.

The qualification of the relationships between participants would ensure consumer protection only ex post, but in the execution of smart contracts, the energy consumer would not have the option of turning to any party who could actively intervene. This explains why the lack of a qualified intermediary capable of disrupting the operation of a smart contract or remedying a problem that has arisen is a limitation that makes this technology still very fragile in the energy field. Who is accountable if the energy produced by a participant does not turn out to be delivered in the required manner and time? How can specific responsibilities be traced back either to smart greed or to the blockchain?

Different is the case with permissioned technology, which is certainly more exploitable in the context of peer-to-peer energy transactions because of its not completely decentralized and permeable structure: the entry of new participants is allowed only if some "nodes" pre-authorize and validate transactions. It is more suited to self-consumption Communities. The mechanism described provides for distributed consents that, while helping to contain liabilities, however, do not allow for rapid distribution of energy flows.

From the perspective of liability regulation, it is necessary to ask whether, in their permitting function, "nodes" can be qualified as intermediaries. The presence of pre-identified "nodes," which is characteristic of permissioned systems, introduces, certainly, an element of centralization in the blockchain structure: in fact, it is possible for participants to appeal directly to them in case of disputes, malfunctions or errors in performance. In such systems, the role of the intermediary is not to provide energy, but is constituted by the set of those entities capable of intervening on the digital network in the management of energy transactions. The particular nature of energy, the delivery of which cannot be fully digitized, leads to the view that full automation of relationships is feasible only if scope is ensured for any external corrective and emergency interventions, and only if participants can identify the parties to whom they can address their requests.

Qualified "nodes" are certainly able to intervene by interrupting the operation of computer protocols and possibly by launching new ones. However, a frequent cause of the malfunction can be traced back to the programming phase of the code which raises further questions about responsibility! Smart contracts have, in addition, various limitations, referable to the computer language, the presence of coding errors (bugs), the impossibility of considering all possible future events. In this sense, an important role in the future is played precisely by the programmers called to develop computer protocols.

In the communities, if the supplier entity cannot be held responsible in the case of supply interruptions, then, in the event that this depended on a software malfunction, it will be the developers who will be held accountable for the failure or inaccurate execution of the transaction.

There are still many doubts about the real possibility of ascertaining the error. In conclusion, on the basis of the distributed contract, the consumer, in his capacity as a participating user of the platform, should be able to turn, in the first place, to the qualified "nodes" that are in charge of transaction management who, in turn, in the event of coding errors or bugs in the system, will then be able to retaliate against the software developers.

CONCLUSIONS

In the light of what has been described, it can be guessed how, with a view to making the energy policy aimed at the dissemination of renewable energy real and concrete, renewable energy communities must function by managing the entire system that characterizes them, efficiently. For the communities described to be said to be fit for purpose, it is necessary to evaluate their operation as well as their results. It is, in fact, possible to deem the architecture adequate, only if the system succeeds in promoting the production of renewable energy, feeding it into the smart grid, activating storage in a way that ensures storage, and meeting the needs of the participants. In addition, at the macro level, it is necessary that the whole mechanism ensures, effectively, a reduction in harmful emissions and that it is cost-effective. To date, due to the relative novelty of the regulatory measures that introduced them, there are not many known cases of energy communities. However, it is possible, from those that can be observed, to draw initial conclusions. Therefore, the following analysis focuses on the description of existing communities, their results and the critical issues encountered.

Energy communities present the advantage of spreading energy efficiency systems with subsequent environmental benefits related to the use of low-emission green sources. To these benefits, those related to the economic savings of the community participants must be added. The 2020 National Energy and Climate Plan (PNIEC) highlighted that these communities do not present security problems, using grids whose efficiency is consolidated. However, initiatives aimed at their diffusion are still little known. Economic support remains instrumental to their diffusion as well as integration with a blockchain platform. What emerged from the analysis is the importance of this platform in terms of regulating both the technical aspects related to "communications" in the energy production system and distribution, as well as the reporting of these exchanges within the energy community. The blockchain is, therefore, essential to ensure that the "system" that constitutes an energy community operates in a way that correctly reflects the productive and consumption aspects and the smart contracts issued ensure the correct attribution of the values exchanged. The work highlighted the advantages offered by the blockchain inherent in its ability to store and trace the activities carried out without a supervisor, with obvious cost savings. Another advantage of the blockchain used in energy communities lies in its ability to prevent points-of-failure by canceling potential attacks on "nodes" that allow the system to continue to operate. The blockchain allows for the correct attribution of exchanged values and, in case of an interruption of energy supply, can trace back to the responsible party. This is of particular importance when the disruption is not due to the distribution and transmission structure, but to the supplier from which the energy is supplied (although often communities are based on common sources). In this case, the community may exercise its right to compensation for damages as a result of contractual responsibility based on the blockchain system recordings. In the case where the disruption is due to the community distribution network, the blockchain can trace back to the point where the system was impeded. In such cases, the grid may also restore the system through automation generated by the blockchain. In conclusion, the report offered a picture of RECs highlighting their technical and normative scope, clarifying that they are a solution rich in benefits but still little used. What is needed and currently lacking is a culture of energy communities whose diffusion still presents many resistances, both for the lack of a large number of successful demonstrations and for the difficulty in finding group agreement. What has been envisioned invites us to think of energy communities as a solution that will require time for its affirmation and that, in the meantime, the legislator must think about ensuring a comprehensive reference framework, which is currently lacking.

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