Winter 12-1-2022

Blockchain and sustainability disclosure: reliable information on renewable energies

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Abstract
Purpose: The energy transition and companies' commitment to sustainability look at new technologies support. We aim to understand how blockchain technology improves the traceability of renewable energy origin and provides reliable information for companies' sustainable disclosure regarding renewable energy use and greenhouse gas emissions.
Design: We conducted a literature review regarding the support of blockchain technology on sustainability disclosure, focusing on reliability through the traceability of renewable energy certificates. We use a qualitative methodology, analysing two case studies.
Findings: The blockchain technology capabilities are recognised by the sector operators, especially for their support in information management and reliability. Blockchain capabilities are identified in renewable energy certification traceability and GHG emissions evaluation, mainly within Scope 3, as reliable information sources for sustainability disclosure. Emerges that the improvement through other devices and regulations might foster the system development.
Moreover, blockchain application in the energy sector is a primary phase that needs more time to develop its potential.
Originality/value: Although there is abundant literature on companies' environmental information, very few studies support the transparency and reliability of renewable energy origin information, considering the technological support of blockchain to guarantee the renewable nature of the energy consumed. First, insights are provided within the idea that blockchain might foster and guide sustainability disclosure through reliable information.
Research implications: The analysis invites interaction between academics, energy sector operators and legislators. It provides reliable information to ensure integration with financial information following an integrating thinking logic.

Keywords: Blockchain, renewable energies, GHG emission disclosure, energy transition

1 Introduction

Blockchain technology is becoming familiar because of its application in several sectors, first in financial one with cryptocurrency exchange and then in many other industries to control the supply chain aspects, e.g. in the agri-food or energy sector.
The energy sector is becoming increasingly disruptive in the European and international discussion, not only because connected to transition energy goals defined before and during the Covid-19 period but also because of the Ukrainian and Russian situation. This situation highlights the strategic value of energy policies and sectors, which must lead toward renewable energy (RE) production, moving further away from fossil fuels.

Moreover, the increasing attention to sustainability in the last few years represents a fundamental point involving communities and organisations focusing their activities and operations on sustainable choices.
Many sectors and industries are adapting their systems to consider social and environmental issues. One of the most important sectors that are changing its system is that of energy.
It is confirmed by UN's no.7 sustainable development goal: it points out the path toward clean energy production hence the increasing use of Renewable Energy Sources (RES) for an overall reduction of greenhouse gas emissions (GHG) [1].
Many countries have set GHG reduction targets and promoted RES for the next few years.
Policies and regulations commonly adopted to reduce carbon emissions in the energy sector are represented by taxes, subsidies, and the Renewable Energy Certificates (RECs) system [2].
For example, in the European Union, Guarantees of Origin (GoO) are an important tool enabling proof of RE's production and informing consumers about energy consumption [3]. Moreover, the companies have increased their propensity to use green energy to combat climate change, and they are interested in reporting on the results obtained in terms also of greenhouse gas (GHG) emissions.
In this scenario, the energy sector is deeply changing its structure, becoming increasingly decentralised and digitalised through many technologies, such as blockchain.
Blockchain, as a distributed and decentralised ledger, guarantees transparency, immutability and tracking of information.
Many blockchain applications in the energy sector could improve trading, distribution and tracking through their distributed and decentralised structure, ensuring transparency and traceability of information.
Mandatory or voluntary sustainability disclosure represents an essential element for organisations, not only financial information but also non-financial information. The companies want to disclose their activities impact on the environment to meet the information needs of stakeholders. In this process, it is pivotal to avoid green-washing phenomena by integrating and sustaining an auditing and accountability system [4].
It is relevant to have technology able to trace the production and distribution of energy to ensure the information reliability about green energy and confirm the nature of used energy. Under these assumptions, the green energy information gains credibility and attests to companies' environmental commitment.
This paper aims to understand how blockchain could improve information reliability about the origin of RE and how it could be an important tool for enriching sustainability disclosure with reliable information.
To reach this aim, it needs to analyse the literature on the energy sector, focusing on changes toward RE solutions development and features and functioning of blockchain technology in this sector with particular attention to blockchain-based RECs (renewable energy certificates) platform. Blockchain-based RECs might be considered a source of helpful information for disclosing sustainability. Through two explorative case studies regarding a TSO (transmission system operators) and a multi-utility company, which play different roles in the energy sector, we examine their position on

blockchain application to provide reliable information about the origin and improve sustainability disclosure of organisations.
The paper is structured as follows: in the second section, we review the literature concerning the use of blockchain technology for renewable energy traceability and sustainability disclosure; the third section presents the methodologies; the fourth section describes the projects and their discussion; the last section highlights conclusions and further research.

2 Theoretical background

The issue of blockchain in the RE sector and its support for a more reliable disclosure requires a multi-perspective approach able to convey various particularities of the topic. For this reason, the literature analysis deals with some aspects. It focuses on the change in the energy sector toward renewable energy sources and the need to disclose RE consumption through sustainability disclosure and GHG emissions reporting. Moreover, it focuses on the support that blockchain offers in terms of green certification traceability for disclosing reliable information

2.1 Blockchain and energy disclosure

The energy transition leads to the change of the energy sector toward a decentralised structure. Promoting renewable energy resources and the widespread adoption of RE power plants update the energy industry and represent an answer to sustainability issues in its three components: economic, social and environmental.
The achievement of sustainability, also by the energy sector, is promoted by European regulation through several acts. These regulations treat sustainability in many shadows involving renewable energy sources and their prevalence in the energy mix, promoting a circular economy, the focus on the waste sector, and the reduction of greenhouse gas emissions [1, 5-8].
Moreover, the Corporate sustainability reporting directive (CSRD) adoption to disclose information about sustainability is a signal of the direction toward transparency in companies' activities impact [9].
The Directive extends the number of companies required to provide information on their activities in terms of sustainability.
Stakeholders also demand more sustainability information from companies: Sulkowski et al. [10] reported that stakeholders and investors increasingly demand sustainability data.
According to Xu et al. [11] the moving toward sustainability requires a shift on shared value within economic, social and environmental values.
The 2020 KPMG report reveals that 80% of N100 companies (100 largest companies in 41 countries) worldwide report on sustainability [12].
It should be noted that disclosing sustainability information is a mainly voluntary activity, apart from some cases, as the European companies involved by Non-financial reporting directive (NFRC) and CSRD [9,13]. The NFRC directive provides five principle topics: environmental matters, respect of human rights, social matters and

treatment of employees, anti-corruption and bribery, and diversity on company board [13].
The great impulse to the sensitive on this topic has been determined even by the growing attention toward climate change and then the impact that organisation activities have on the environment in terms of produced GHG emissions.
The relevance of environmental information is increasing because stakeholders and investors also request that the companies disclose their environmental impact. Manes-Rossi et al. [14] reported many studies where disclosure emerges as an instrument for creating a good public image.
Moreover, the increase in awareness related to sustainability issues reflects the presence of organism such as the GRI [15].
Many studies analysed sustainability disclosure and reporting and their environmental component.
As reported by Solikhah and Maulina [16] is possible to define Environmental disclosure as "a form of corporate responsibility for the impacts caused by manufacturing activities".
Carreira et al. [17], in their study, analysed the increase of environmental reporting and disclosure level and presented an environmental disclosure index that involves, among others, environmental indicators.
Collecting reliable information about activities' environmental impact might be important to improve the sustainability disclosure activity. Information about energy consumption, renewable energy use, GHG emissions and saved emissions are involved.
The relevance of this information is also represented by the adoption as an environmental indicator in GRI indicators within GRI Standard 302 for energy and 305 for emissions [18-19].
In fact, to support processes and facilitate companies on disclosing sustainability, the commonly adopted approaches are the Global Reporting Initiative (GRI) and Integrated Reporting (IR) and GHG protocol for GHG emission.
These approaches offer a guideline within several environmental indicators about GRI, strategies, governance and performance factors for IR.
The GRI guidelines represent an internationally accepted framework for comparing sustainability reporting; GRI "allows information users to make informed assessments and decisions about the organisation's impacts and contribution to sustainable development" [20].
An important instrument to provide disclosure about the impact of activities in terms of GHG emissions is the GHG Protocol. This protocol categorises emissions into three groups called Scopes.
The Scopes involve the emissions generated by the organisation internal activities (Scope 1), emissions generated by purchasing and consuming energy in relation to its source (Scope 2) and emissions related to up and down-stream in the value chain (Scope 3) [21-22].
To ensure transparency, consistency and accuracy in the information declared, the Scope 2 and 3 are constantly under review [22].
In recent years, attention to scope 3 is increased because the relevant quantity of emissions accrues along the value chain [21].
Transparency of information and reliability is important for disclosure practices.
The need for reliable information is moving organisation toward sustainability. [23]

To reach some types of sustainability information involving multiple external parties is necessary [4].
As reported by Corazza et al. [23] it should be noted that sustainability reporting and disclosure are tackling important issues such as:

- manipulation of data;
- materiality of sustainability information provided;
- global governance of sustainability movements and standards.

To face the transparency, reliability and traceability of information, several authors identify blockchain technology as a tool that might support the information system; for these features, many sectors have been involved in the application of blockchain, such as the waste, agricultural, food, and transport sectors [22-24].
As reported by Wang et al. [25], integrating energy technology and ICT is inevitable and blockchain plays a fundamental role as Energy Blockchain.
According to Friedman and Ormiston [26], blockchain might be helpful as a data record system within an environment where technological innovation is a sustainability tool and technologies like AI and IoT are fundamental in data trustworthiness.
According to Bakarich et al. [4], blockchain allows sustainable information and data to be tracked and stored reliably and involves reporting GHG emissions.
Blockchain technology is a relatively new technology born in 2008 during the financial crisis. The technology has been presented as a peer-to-peer platform able to create and exchange the cryptocurrency Bitcoin [26].
It was hailed as a disruptive technology because it allowed the peer-to-peer value exchange without third parties as guarantors of the transaction, overcoming the double spending problem [27].
The ability to solve problems related to controller absence, the system of value guarantee and transaction anonymity, ascribed popularity to Bitcoin as the first reliable and safe decentralised digital currency mechanism [28].
Blockchain is a distributed and decentralised ledger with a chained blocks architecture that follows a chronological order.
The ledger has the function of storing transaction information.
These transactions are recorded through a consensus mechanism inside a block that will be added to the chain. New blocks can be added, but the previous ones cannot be edited or deleted. Blockchain uses cryptography and hash functions to make the system immutable and save information. The hash function creates a mathematical bond between blocks linking them. The newly generated block contains the previous block hash code.
The ledger can be owned by every participant in the peer-to-peer network.
It is possible to identify three different types of blockchain relating participation mean to the network:

- The permissionless blockchain, public with open access where everyone can participate in the network and own a copy of the ledger (Bitcoin and Ethereum are permissionless);
- The permissioned blockchain, with restricted access for a defined group of participants through a validator [29];
- The consortium blockchain is hybrid semi-decentralised blockchain with a network composed of one part private and one part public [30].

An important element in developing blockchain technology is the smart contract. A smart contract is a computerised transaction protocol that verifies, negotiates, or executes an agreement's terms [31].
Smart contracts allow the automation of trusted transactions without the guarantee of a third part with potential application in many sectors, as the energy one [28].
To trace the development of blockchain technology, Swan [32] offers an important contribution that proposes three categories to the revolution generated by blockchain. Swan 2015 identified a Blockchain 1.0 as associated with currencies and cryptocurrency exchange systems, the Blockchain 2.0 refers to contracts with all financial, economic and market applications of the technology and, ultimately, many other applications in several sectors with Blockchain 3.0 [32].
Blockchain applications could improve transparency and data security and decrease transaction costs, optimising processes [33].
Moreover, blockchain technology has facilitated and made more efficient processes, such as accounting, accountability and reporting activities.
As reported by Fullana and Ruiz [34] the implementation of an accounting blockchain-based system presents a decentralised structure with a distributed authority and control; furthermore, to deepen the way accounting information system is affected by blockchain, they present a list of 17 effects:

- certainty about the completion of transactions;
- improvement in vendor/consumer selection in the supply chain;
- alignment of organisational goal management actions;
- a more harmonious relationship between managers and owners;
- automation of some transactions;
- verification that accounting rules have been applied;
- avoidance of mistakes;
- reliability in the information;
- deterrent against concealment;
- confirmation for both parties that the transaction has occurred;
- security in terms of privacy of the information;
- evidence that information has not been tampered with;
- inability to alter information;
- reduction in lost data;
- trails allowing for the transaction to be traced;
- control of management actions;
- and detection of any needs throughout the process.

According to Bakarich et al.[4] we observe that the application of blockchain technology and its benefits within the supply chain has a logical extension to auditing and verifying information stored to meet sustainability reporting requirements.
As reported by Sahebi et al. [35], blockchain technology might offer a change in terms of accountability, traceability and reability as a principal contributor within renewable energy supply-chain (RESC).
These features might support the energy sector and the operators' network both to enhance accounting and sustainability reporting or disclosure. In this context it could be highlighted the role playing by blockchain in guaranteeing the traceability of

renewable energy origin improving companies' disclosure on the use of RE and GHG emissions.
The tools identified by the industry for obtaining information about the origin of renewable energy are the Renewable energy certificates (RECs) or Guarantees of Origin (GO).
Moreover, green certificates and carbon trading are among blockchain applications on the energy sector, according to Andoni et al. [36].
Section 2.2 will introduce the RECs system and the cases from literature where they have been supported by blockchain technology.

2.2 Renewable energy certificates as reliable information source

As mentioned above, RECs are essential to trace and guarantee renewable energy origin.
RE traceability answers to the need of a transparent and reliable disclosure about energy consumption for those who purchase that energy. Within a context where GHG emission reduction goes through increasing renewable energy sources (RES) consumption, traceability gives consumers an additional element to take decisions; besides the price, they also consider the origin of energy.
Moreover, energy traceability might represent a way to obtain information for accounting for the quantity and electricity nature [37].
It is currently impossible to physically track the energy because once produced, it enters the grid and mixes with energy produced by other plants with different sources; for this reason, the mix composition is unknown. The certification system allows to select renewable attribute of physical energy and separate both enabling independent trade [38].
As said before, Renewable energy certificates, even known as green certificates or guarantees of origin (GO), in the European Union are a common helpful tool to that purpose. This important tool aims to inform consumers whether the energy consumed is from renewable sources [39].
Many countries have adopted this policy, creating a regulation for certifications exchange.
In the European Union many directives regulate this market. GO appears with Directive 2001/77/EC for the first time to regulate the local and international exchange of certificates [40].
Every guarantee of origin issued corresponds to 1MwH produced. [41] According to Spinnel and Zimberg [42], RECs are defined as tradable commodities that are non-tangible.
As required by EU regulation, GO minimum content is about the resource type, the date of production and the plant place where it has been produced.
Gkarakis and Dagoumas 2016 [37], consider these important tools and list their aims: a) the claim of subsidies, b) the support of electricity bill energy mix disclosure that represents the set of primary energy sources used for electricity supplied and c) prove of compliance.
The European structure of guarantees of origin considers the possibility of allowing exchanges between different countries to promote a system standardisation called

European Energy Certificate System (EECS-GO); through the European platform AIB (Association of Issuing Bodies), it is possible statistic monitor decreasing pollution.
The exchanged certifications represent a complex market where domain and supply create many transactions.
According to Andoni et al. [36], blockchain is a suitable technology, because of its traceability, decentralisation and immutability features to reduce transaction costs, obtain an expansion of the certifications market, increase the transparency level and prevent the double spending problem [43].
In this scenario, certification issuing is a centralised process where the central authority is exposed to risks of errors and fraud [25].
As Yamaguchi et al. [2] reported, blockchain has been implemented in Brazil by a company that started with RE certificates issuing; the issuing activity intensification increase time-spending auditing operations, so a new system has been adopted and then improved with blockchain technology. This choice assigns high security levels on issuing process fostering traceability [2].
Another case study analysed by Spinnell and Zimberg [42], is about North American Transmission System Operator (TSO) PJM EIS; they applied private blockchain technology to a single information system named GATS (Generation Attribute Tracking System) that aims to report and verify compliance requirements on issuing operations. Even in this case, blockchain intends to improve RECs internal accounting through decreasing operational costs and to another hand blockchain guarantees transparency for participants and immutable records for auditing [42].

3 Methodology and research design

To fill the literature gap, this research highlights if and how blockchain in the renewable energy sector facilitates the management information flow, affecting the disclosure of green energy and GHG emissions. We use a qualitative methodology, considering two Italian companies operating in the energy market with different roles that have developed blockchain-based projects [44][45].
Terna Spa is the Italian transmission system operator, a listed company born in 1999 and Europe's biggest independent grid transmission operator. Terna plays a fundamental role in the national electricity system because it manages, maintains and develops the Italian high-voltage grid and energy dispatch.
Terna is evolving its business model following the energy transition toward RE use based on innovation, sustainability and several capabilities.
Hera group is an important Italian multi-utility that works in a catchment area of 4 million people. Hera group activity is articulated in three main areas related to providing water services (such as the aqueduct, purification and sewerage), energy services (such as electricity and gas supply), and environmental services for waste collection and disposal.
For this reason, it is sensitive to sustainability issues and dedicates reports on every activity it carries out.
From a methodological viewpoint, the projects implemented by the two companies represent exploratory cases in which the empirical evidence can support the formulation of a theory, which will be tested in future research. According to the literature on methodology research, the exploratory case study (compared to the descriptive and

explanatory ones) is appropriate when it is quite difficult to draw on similar empirical evidence from previous literature [46]. Particularly, this type of empirical analysis aims to highlight what happens in the presence of a given phenomenon, which is the use of blockchain to manage the information about the production, distribution, use and disclosure of RE.

To ensure the necessary methodological rigour, we represent the research design in this work in Fig 1.

Starting from current state of literature, this paper aims to explore blockchain technology use on RE, for more reliable information about the RE origin.

The literature analysis has considered the studies focused on the certification issues to assure the origin and traceability of renewable energies. This literature has been accompanied by studies that deal with green energies and GHG emission disclosure. Although there are numerous studies on this topic, few focus on blockchain capabilities to improve the quality of this environmental disclosure through reliable information.

The theoretical proposition from the literature review is validated by the empirical analysis, focusing on two projects adopting blockchain in the Italian market sector, in which this issue has not been sufficiently investigated.

The choice of cases was dictated by the fact that these two companies operating in the energy sector have adopted interesting projects intended for further developments that use the blockchain. The analysis was conducted using institutional information related to chosen organisations and a semi-structured interview. The interviews were addressed to key actors of blockchain projects, with a half an hour duration, and were tape-recorded and transcribed. The interview has been conducted seeking to understand the blockchain role in the energy market and energy disclosure from two perspectives: its development strengths and limitations.

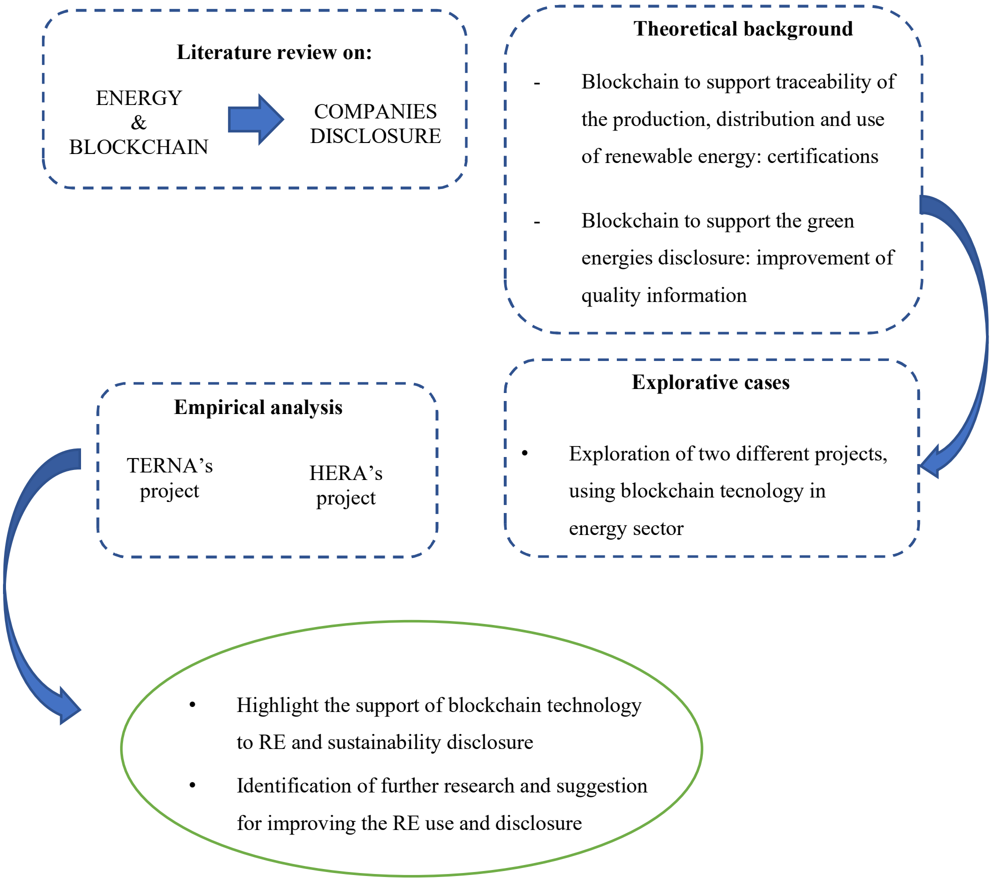

Fig.1 – Research design

4 Projects description and discussion

The first examined case is Terna with Equigy project.
Equigy is a joint venture between several European TSO, including the Italian Terna spa. This project is defined as a crowd-balancing platform that connects and facilitates operators of electricity balancing markets. Equigy platform involves different system actors, including transmission system operators, distribution system operators, and eventually, energy community, power exchange, aggregators, and not still existent validation data providers. It works to enable smaller distributed flexibility assets to take part in the energy system through aggregation.
Equigy applies blockchain technology, implemented by the Hyperledger Foundation of IBM that is closed and permissioned with channels only some actors can access. This platform doesn't present a tokenisation system and connects actors quickly. Moreover,

the many processes that require transactions cross-blockchain, are recorded and shared with the right market players and it provides assurance "*that information is immutable, not-modifiable and are the single version of true*".

In a general view, blockchain provides security of what happens, and no one can contest it and if a transaction is recorded there is no need of validator or regulator because information remains unchanged and there is a proof of delivery.

Exploring the renewable energy traceability issue and its position about it, Equigy is focused on balancing market operations. The judgement expressed by the interviewee on RECs is that GO system would be very useful but needs to be reset in the hypothesis of blockchain application. Moreover, he says that it could be very important to adopt devices to track energy flow although they are still not available technologies.

The complex structure of Equigy with a large network generates a lot of information.

From the interview, it emerges that this platform could improve the collection of information for sustainability disclosure and emissions. To be clarified that Equigy is an IT organisation with no assets that works on software and, for this reason, has very low direct emissions. Nonetheless, it is possible to estimate saved emissions relating to the transition from thermal power plants to our distributed sources. This information might integrate GHG protocol with particular attention on the indirect emissions associated with the value chain included within Scope 3.

The second examined case is Hera Group

In this interview, Hera group presented two different projects that is working on.

The first project joins sustainability to blockchain technology. Hera group presented a project born from the idea to create a tool capable of stimulating sustainable behaviours by people and citizen; the project has been launched in an Italian competence center and it is based on a system of incentives for sustainable behaviors.

The innovative context has driven towards blockchain technology implementation.

According to respondent, the project could be interpreted as "*a vertical loyalty program, but through blockchain technology the great challenge has been to move from a vertical program to transversal one involving other actors*."

Moreover, through this system, emissions related to behavioural habits can be calculated.

Another project is related to a cashback circuit promoted by a municipality where Hera group provides the virtual wallet tool to integrate their services in the future.

The point of arrival is to increase behaviours and incentive systems in both project cases.

This interview emerged as the sustainable issue is approached from a consumer point of view regarding reducing, saving and calculating emissions.

Also, for Hera group, the renewable energy traceability issue is confined to reporting only Guarantees of origin on the energy mix of purchased electricity because it is not an energy producer but a distributor. That means Hera group purchases RECs to guarantee to consumers the origin from a plant that uses renewable sources.

Emerges on this topic that thinking on a traceability system could be important a real-time sharing approach to avoid a REC being sold twice to ensure and obtain reliable information.

About indicating blockchain technology as a possible solution, the respondent says that "*taking part in a supply-chain and adopt a tool to certificate what you buy and how you use it, is important*."

Following the interview and focusing on sustainability disclosure issues, the respondent declares Hera's sensitivity on reporting and its work for reporting downstream toward the consumers for Scope 3.

During the interview, an innovative project idea emerged that leads to implementing scope 3 reporting and aims to create a carbon certificate issuing system able to trace certificates. It is highlighted that the development and realisation of such a project need appropriate regulation.

Concerning blockchain application on GHG reporting, the opinion that emerged is that blockchain is a "toolbox" with several tools. The difficult part is to "assemble the service" considering the scenario where the blockchain will be applied and its form: public or private, open or closed, how many transactions it could process, etc.

Forecasting a future role of multi-utility in the decentralised energy sector, the blockchain would be a useful tool to regulate transactions with consumer, producer and prosumer also utilising a tokenised system and recording information helpful not only for Scope 1 and 2 reporting but also in this case for Scope 3.

5 Conclusions and further research

To clarify how blockchain technology might be useful for providing reliable information to support sustainability disclosure, this paper highlights some important issues regarding its application. Focusing on renewable energy sector, it is noted that in this sector, relationships are characterised high quantity of transactions, especially in TSO case but also in DSO and multi-utility case; this technology might provide a great contribution because of being capable of making information immutable.

The possibility of obtaining more reliable information goes toward the direction of sustainability disclosure and GHG emission reporting as emerged from the interviews and as reported in the literature.

Information contained in the certificates might support the disclosure of the energy mix and the consumption of electricity produced by RES. The same information could support GHG emission disclosure regarding Scope 2, and emissions save as reported in the literature.

As indicated above, RECs might represent important information sources, and blockchain application could enhance it. However, it is still difficult to implement a RE traceability system based on blockchain because of different regulations around the world.

Energy Web Foundation' project is one of the few cases where a public Blockchain has been implemented for the certification system, and the platform manages transactions both for energy market and certifications market allowing RE and GHG emissions traceability.

This work highlights the awareness of both respondents on blockchain capabilities to support information reliability; moreover, its implementation in operators' networks enables reporting on Scope 3 related to value chain emissions. The difficulty reported by the literature in determining Scope 3 emissions emerged during the interviews.

For future studies, it is interesting to analyse cases where blockchain is implemented in projects that promote sustainable behaviours and also explore the application of blockchain on value chain creating networks to enable Scope 3 reporting. Although the energy sector is changing, the use of blockchain seems to grow with it; for this reason, it will be interesting to monitor the evolution of these cases.

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