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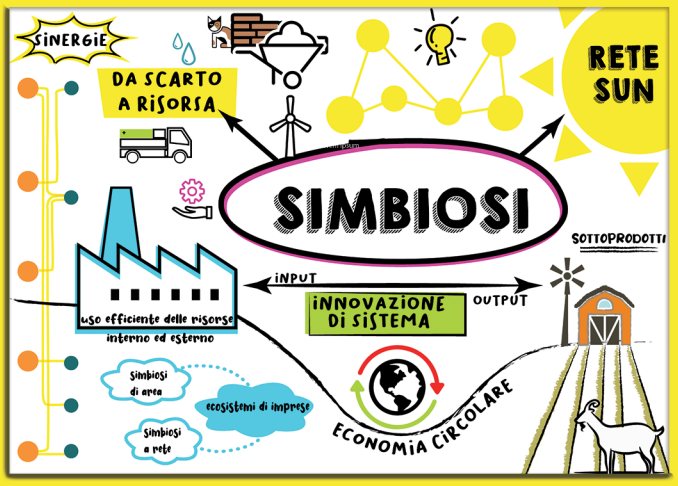

Italian National Agency for New Technologies, Energy and Sustainable Economic Development

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Symbiosis Users Network

Il contributo ed il potenziale della Simbiosi Industriale per la transizione ecologica

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BLOCKCHAIN TECHNOLOGY TO DRIVE INDUSTRIAL SYMBIOSIS WITHIN CIRCULAR SUPPLY CHAIN MANAGEMENT

Valentina Ventura[1]*, Marco La Monica [2], Marco Bortolini[1], Laura Cutaia[2], Cristina Mora[1]

[1]*Department of Industrial Engineering, Alma Mater Studiorum - University of Bologna, ITALY*
[2]*Laboratory for Resources Valorization, Department for Sustainability - ENEA, ITALY*
(E-mail: valentina.ventura7@unibo.it)
*Corresponding author

ABSTRACT

Over the past few years, digital technologies created new opportunities to tackle sustainability challenges. The strategic management of supply chains is essential to close the loop among production, consumption and waste valorization echelons. This requires a strong correlation, integration and collaboration among the involved entities. Blockchain technology could have the potential to spread Circular Economy (CE) principles within green supply chain, allowing to track tangible and intangible assets within a peer-to-peer network. In particular, this working paper explores whether a blockchain platform can be implemented into an Industrial Symbiosis (IS) context. A methodological framework is presented including all the synergies that the blockchain technology can boost for a consistent data flow along the supply chain. Preliminary discussions from the field are proposed, also, together with existing constraints and a roadmap for the future steps.

keywords: *Industrial symbiosis; blockchain; circular supply chain; sustainable economy; waste valorization.*

Introduction

In the last decades, digital technologies are creating new opportunities to tackle sustainability issues, encouraging companies and final users to move towards Circular Economy (CE). In this context, it is essential to find solutions that allow reducing the negative consequences on the environment without jeopardizing economic aspects [1]. Industrial Symbiosis (IS) rises as an emerging paradigm and suitable option [2]. To pursue the goal of redirecting waste and by-products of a company as inputs for other businesses, a key issue to face is the matching of resources of all the entities taking part to the supply chain network, the managing of relationships among stakeholders and the mapping of material flows along the system [3]. Advanced solutions to manage the flow of information is essential to guarantee a smooth interconnection among the supply chain entities. Blockchain is a viable enabling technology to manage distributed and complex informative

systems with multiple origins and destinations of the data flow. A blockchain is a distributed ledger where data are shared on a peer-to-peer network. Once a new transaction is recorded on the system, it builds a block that is linked to the others, creating a chain. Blockchain technology became popular after the 2008 financial crisis and through the development of cryptocurrency and Bitcoins [4]. Although the primary application was in the financial sector, the features of blockchain inspired several sectors, including supply chain management [5]. Blockchain provides several improvements regarding the traceability and transparency of data. This is a crucial issue for both IS and supply chain management. Since it uses a distributed public general ledger, blockchain is a useful way to manage supply chain informative flows. This technology is helpful because it decreases human errors, reduces information asymmetries, eliminates fraudulent activities, improves reliability throughout the chain, tracks products and related information and increases consumer and supplier trust [6].

This working paper aims at establishing whether and how blockchain technology can support IS to strengthen circular supply chains. The goal is to provide an updated review of both IS and the blockchain technology as a starting point to preliminary set a two-step methodological framework, i.e. conceptual and operative, including all the entities and win-win synergies that the blockchain technology can enhance for a consistent data flow.

The paper is organized as follows: Section 2 presents the aforementioned two-step methodological framework, Section 3 raises preliminary discussions about the state-of-the-art, while the last Section 4 concludes this working paper outlining the next research steps.

A two-step methodological framework

This section proposes a methodological framework made of two steps supporting the decision of integrating a blockchain platform into IS networks. The first step deals with a conceptual scheme including five branches, i.e. technological, economic, social, environmental, and legislative, to offer a logical pattern guiding practitioners in applying blockchain technology in CE networks. The second step starts from the outputs of step one presenting a more operative approach and a potential “to-be scenario” in case of blockchain will be effectively implemented within IS networks.

First step: conceptual framework

The conceptual framework considers the abovementioned five branches of assessment. Each branch has different factors to consider and related tools, KPIs and benchmarks for evaluating the feasibility to introduce blockchain technology into an IS network.

Alongside qualitative aspects, few quantitative techniques have been included for a holistic problem evaluation. The diagram in Figure 1 represents the main elements to consider. In the middle of the chart, a hypothetical network of firms, i.e. the IS system connected by blockchain technology, is exemplified to represent its compliance to technological, economic, social, environmental and legislative branches.

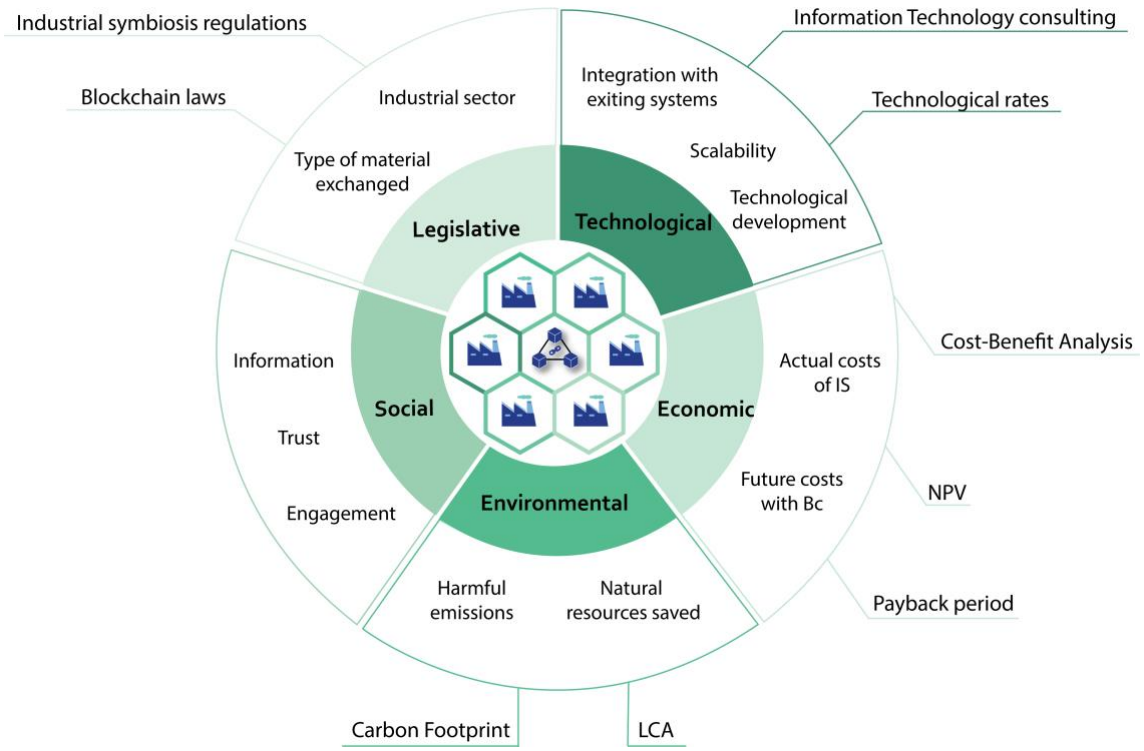

Figure 1. *Conceptual framework for a feasibility study to introduce blockchain technology into IS networks*

Second step: operative framework

Following the conceptual scheme, after collecting outputs from the feasibility study, an operative layout is suggested to link an IS network and a blockchain system, presenting a possible reference configuration. To develop the framework, the analogies between IS and blockchain technology are highlighted. They can both be considered as networks, ecosystems and platforms. Blockchain is a distributed peer-to-peer network where data are stored and shared among participants, while IS is a network of companies where resources can be traded through the support of a digital platform, following CE principles. They are both characterized by the presence of actors which collaborate for the development of an ecosystem and for the creation of synergies. The following framework assumes that blockchain technology can be beneficial as a link between

supply chains, by endorsing the end-of-line of one company and the beginning of another (Figure 2). Two manufacturing companies can share data about their input needs and waste or by-products that they want to dismiss through a blockchain platform. Waste generated from an end-of-line of a company is delivered to another company, which utilizes it as an input. Smart contracts are an essential tool to mediating relationships between different organizations and their execution can simplify the approval from multiple actors of the digital agreements. Another element introduced within the new system is an incentivization mechanism through digital tokens. When business waste is transmitted to another company instead of a landfill, a token is awarded to both supply and demand sides. This tool is fundamental for incentivizing parties to create synergies with the available resources and enhancing their engagement into the IS network.

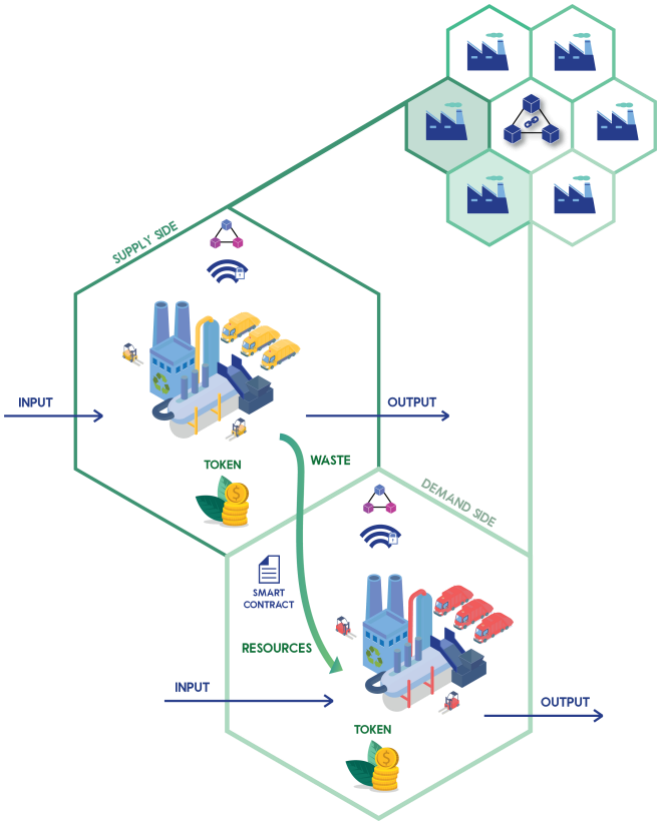

Figure 2. *Operative framework for a blockchain-based IS network.*

Discussion

The literature is starting to investigate the use of blockchains in IS contexts. Several issues are still open [7], e.g. the most of digital platforms are not available to public, the lack of information infrastructures, the insufficiency of functional support, procedural

and technical difficulties in heterogeneous data collection and storage, the lack of willingness, trust and cooperation among companies, difficulties in customizing digital solutions to case studies, etc. In this context, the introduction of the blockchain technology could be a chance to overcome IS coordination problems rising when the number of firms is high and it helps to automate tasks that are currently performed by human operators, subject to errors. Blockchain allows information exchange and transparency reinforcing trust among individuals who participate to the IS network. Several research efforts highlight the potential of blockchain technology in greening supply chain CE models, but the existing literature refers, only, few actual real cases that link blockchain technology to IS. The gap between the wide range of academic literature dedicated to blockchain technology and the few studies about practical applications is an urgent lack to cover, especially regarding blockchain and sustainability. The need of experimental evidences about sustainable advantages that blockchain technology offers, the optimization of CE networks through digital technologies and studies regarding methodologies for integrating IS and blockchains are good examples of research needs that deserve immediate attention [8].

Conclusions

Blockchain is a potential and powerful technology to strengthen Industrial Symbiosis (IS) in the modern hyper-connected and real-time industrial context. Its potential is discussed in this working paper and integrated into a two-step methodological framework supporting decision makers and institutions in the design and management of circular supply chains. The conceptual framework stresses five branches of assessment, i.e. technological, economic, social, environmental and legislative, while the next operative framework encourages the goal of setting up synergies among the supply chain nodes in the direction of Circular Economy (CE), waste and by-product valorization. Despite good basis for the wide acceptance of the IS concept already exists at the institutional level, lot of steps are required to create commitment among the operative actors to push them into the concept and to stress the benefit they can gain. These challenges, together with quantitative methods and multi-target approaches to quantify opportunities for all the stakeholders are among the expected next steps of this work.

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