

Smartlabel: A proposal for applying blockchain in the use of the PROCEL seal

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ABSTRACT

This study proposes a smart energy efficiency label (smart label) using blockchain technology to ensure secure access, traceability, validation, and certification of all information related to the energy performance of labeled equipment. The methodology involves mapping the process of using the PROCEL (National Electric Energy Conservation Program) label on a typical household appliance within the Brazilian Labelling Program (PBE), showing the application of blockchain technology throughout the process. With the PROCEL label, blockchain can document the entire lifecycle of the equipment, tracking every step until it reaches the consumer. This allows consumers to trace and verify the results of tests the equipment has undergone, make comparisons between various products, understand the ecological impact of the product's development, and ensure that the product is not counterfeit. Labels, logos, and quality descriptions reduce information asymmetry regarding product quality, providing consumers with greater confidence in their purchases. Blockchain technology addresses each of these aspects by enabling traceability, certification, verification, and security of the information presented on the equipment. The smart label holds significant potential to enhance agility, transparency, security, interoperability, auditability, reliability, and product traceability, thus benefiting both consumers and manufacturers by fostering trust and promoting the production of more energy-efficient products.

Section: RESEARCH PAPER

Keywords: label; seal; energy efficiency; blockchain; smartlabel

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1. INTRODUCTION

The quality of products can often be presented through their labels, tags, or seals. Research demonstrates that the product seal is an item that affects consumers' product choices. Similarly, traceability labels can increase consumers' purchase intentions [1].

Consumers require information to make decisions, and logos, labels, and quality descriptions provide information to help consumers differentiate products and manufacturers in terms of the delivered product quality [1]. A label is a sticker, which can be either compulsory or voluntary, affixed directly to products or packaging, containing important information. As for energy efficiency labels, they usually provide information about the energy consumption of the product. Thus, the objective of energy efficiency labels is to convince consumers to buy more efficient products and manufacturers to produce them more

efficiently, as well [2]. Labels help educate consumers and can contribute to further savings.

These labels allow for the comparison of energy efficiency among similar products. However, they will only be effective in assisting consumers in choosing a quality and more energy-efficient products if there is a variety of similar and labelled products available in the market [2].

Energy labelling programs are a reality in most countries worldwide and are a key element of energy efficiency policies [3]. As investments in energy efficiency often have a high return rate, energy efficiency labelling campaigns can influence consumer behaviour and lead to greater competitiveness of energy-efficient products in the market [4].

Compulsory energy efficiency standards are generally the most effective way to rapidly improve the energy efficiency of equipment. Conversely, voluntary energy efficiency standards provide an alternative option to encourage energy efficiency programs [2]. Several steps should be followed to establish

energy efficiency standards and labels. According to [2], it is necessary to establish testing procedures, standards, labels, and incentive programs.

Energy efficiency standards aim to define the minimum energy performance of something, often prohibiting construction or sales when minimum levels are not met. This encourages manufacturers to invest in more efficient product development and construction, reducing overall energy consumption or investment to meet this demand [2]. Regarding [2], it is essential for the standards that establish minimum energy efficiency levels to be regularly updated and try to keep up with trends in more developed countries, to compel manufacturers to upgrade and develop more energy-efficient products.

Beyond conveying information about equipment energy efficiency, product labels can also inform consumers about a product's provenance—including its origin, authenticity, integrity, and chain of custody—thereby supporting more informed purchasing decisions. Labels and tags that ensure traceability help reduce information asymmetry regarding product quality, increasing consumer confidence. One technology that addresses this gap is blockchain, which supports traceability, certification, verification, and data integrity for the information presented on equipment labels. This transparency enables consumers to more accurately assess the qualities of a specific product. The immutability of the blockchain and shared access to data among participants in the supply chain can play a significant role in achieving information transparency throughout the process [1]. Blockchain technology has characteristics that can be used in various sectors and, according to [1], it is a decentralised and public digital ledger where transactions are recorded and added in chronological order to create permanent and tamper-proof records. This goal can be achieved by recording transactions in separate blocks, which are cryptographically linked to ensure high levels of security and validity. Each block is assigned a unique reference number or code, known as a "hash", which is linked to the subsequent block via a link. This process ensures immutability, meaning that if a specific block needs to be altered, all connected blocks must be modified accordingly [5]–[7].

In Brazil, the PROCEL Seal (National Program for Electric Energy Conservation) is a voluntary program designed to identify products with the best energy efficiency levels, benefiting society and companies while promoting their brand. PROCEL was created in 1985, coordinated by the Ministry of Mines and Energy (MME), and executed by ENBPar (Brazilian Company of Shares in Nuclear and Binational Energy). For equipment that uses fuels (gas, oil, gasoline, etc.) as an energy source, particularly for heat generation, the CONPET Seal is applicable with the same objective as PROCEL, promoting equipment efficiency and reducing emissions and resource consumption [8].

The PBE (Brazilian Labelling Program) was established in 1984 with a primary focus on improving energy conservation in the industry. Currently, it is coordinated and regulated by INMETRO (National Institute of Metrology, Quality, and Technology) [9]. The main objective of the PBE is to promote energy conservation by using informative labels on machinery and equipment that describe their energy consumption. To achieve this goal, the program implements technical standards for each type of equipment, encouraging continuous improvement in performance and equipment quality [8],[9].

In this first phase, the products undergo tests for electrical safety and efficiency levels following the Conformity Assessment Requirements issued by INMETRO, obtaining the ENCE

(National Energy Conservation Label) at the end of the process. The ENCE assigns an energy efficiency level to the product based on the tests, ranging from 'A' to 'D', with 'A' being the highest level of efficiency and 'D' the lowest. After approval in these stages, manufacturers/importers can request the authorisation to use the PROCEL seal, which is granted to the top 25 % of the most efficient products in the 'A' class of the same category [10].

According to [11], blockchain can be applied in the label process to reduce bureaucracy, improve data management, enhance information security, lower transaction costs, and increase the reliability, transparency, and auditability of the processes. It can generate new services, such as certification of new products, evaluating equipment and buildings, monitoring the life cycle, and facilitating data correlation from certificates.

Furthermore, as stated in [12], blockchain can be applied in the equipment testing stages. Since the equipment submitted for the ENCE label must undergo tests in accredited laboratories, the standard ABNT NBR ISO/IEC 17025:2017 applies, which establishes all the requirements that laboratories must meet to ensure traceability and result reliability. Blockchain can be adopted as the Digital Calibration Certificate (CCD) for the equipment used in the tests and throughout the process, using smart contracts.

Blockchain is already well discussed in the literature regarding its application in the field of metrology. There is a lot of literature on the use of blockchain for digital calibration certificates, metrological traceability, smart contracts, and conformity assessment. For example, in [13], a system for managing and visualising metrological traceability using Ethereum blockchain technology is presented. The goal is to provide an efficient and secure solution for managing digital calibration certificates (DCCs) and metrological traceability.

In [14], a model is proposed for the design of a blockchain network involving National Metrology Institutes and other organisations interested in promoting solutions related to legal metrology and conformity assessment. The work aims to present a permissioned blockchain architecture for creating a network composed of independent organisations with decentralised management, with a focus on application in legal metrology and conformity assessment. In [15], the existing literature on blockchain and legal metrology is reviewed, along with examples of use cases in other areas.

Examples of how smart contracts and decentralised autonomous organisations can be applied in legal metrology systems are also presented. The objective is to explore the potential of blockchain technology in legal metrology, specifically in the areas of smart contracts and decentralised autonomous organisations. In [16], a vehicle speed measurement system was implemented using the Hyperledger Fabric platform. The author's objective was to propose a blockchain-based solution for implementing distributed measurement systems.

However, no literature was found to discuss the use of blockchain in conjunction with traceability for a conformity assessment process applied to energy efficiency labelling programs, such as the PROCEL Seal.

In this context, blockchain can be applied throughout the entire certification process to enhance reliability, auditability, product certification, and transparency. Its integration into the PROCEL seal framework presents several advantages, such as enabling traceability across the entire value chain, from product conception and registration to its end of life. By requiring participation from all actors involved in the value chain, whether

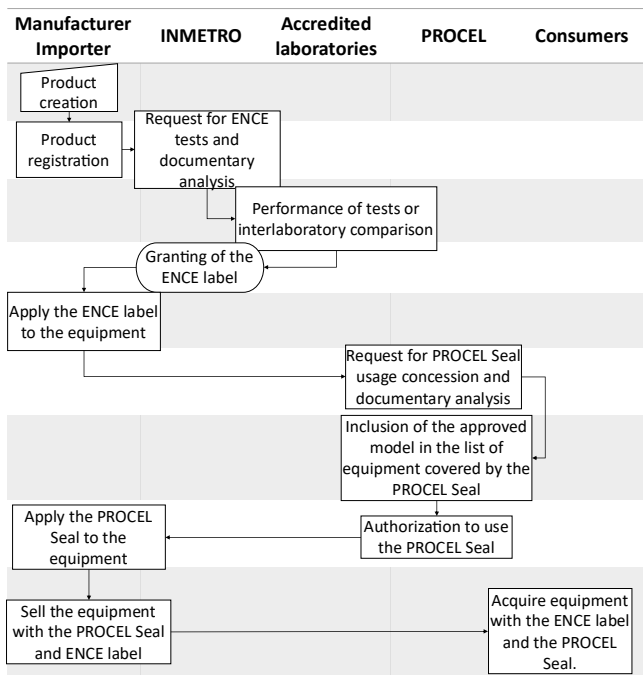


Figure 1. Main stages of the process for granting the PROCEL Seal. Source: Own elaboration.

private or public entities, blockchain can establish a unified and secure system of information exchange. This comprehensive integration provides a robust foundation for proposing an intelligent energy efficiency seal based on blockchain technology [11].

This work aims to propose an intelligent energy efficiency seal (smart label) using blockchain technology for secure access, traceability, validation, and certification of all information related to the energy performance of labelled equipment. Notably, the paper is structured into four sections. In this first one, the subject and other aspects related to the objective of this work were introduced. The second section provides a detailed description of the methodology applied in this work. The third presents the results, and finally, in the fourth section, the conclusion, final considerations, and suggestions for future work are presented.

2. METHODOLOGY

The methodology of this study involves mapping the process for granting the PROCEL seal of a typical household appliance from PBE, demonstrating the application of blockchain technology throughout the process stages. This process has nine steps, and five actors are involved, as can be seen in Figure 1: i) manufacturers/importers; ii) INMETRO; iii) accredited laboratories; iv) PROCEL; and v) consumers. The summarised structure of the blockchain used in this work is presented in Figure 2.

The proposed structure provides for adding a new block to the information chain, at each stage of the process involving various stakeholders, as new information about the equipment is generated. When a consumer requests access to information about that equipment through the PROCEL Seal label, the entire chain is verified by a network of computers, following the chosen algorithm. Once the information contained in the chain about the equipment is validated, only the information previously authorised at the consumer level is finally presented.

Thus, following these principles and incorporating new features within the established framework, it was identified how blockchain could be employed at each stage of the product certification process until obtaining the PROCEL seal authorisation and the product reaching the hands of the consumer.

3. RESULTS

In Figure 3, the blockchain is applied within the first two stages of the PROCEL Seal granting process. These initial stages are internal processes and the responsibility of the supplier/importer. This study assumed the premise that these actors would use blockchain to demonstrate the potential results of using blockchain from the conception of product development. Information related to the research and development of the product is added with the insertion of the "A" information block. In the proposed framework, hash A contains all the information about the research and development of a new product. This may include information such as market research results, design, technical drawings, and all project management related to that product. This information is crucial, at this stage, for the company, and due to the security and immutability characteristics of blockchain, no unauthorised or undesirable changes would be possible, ensuring secure storage of the information. In hash B, information about the materials and the energy resources used in the equipment is added. In hash C, manufacturing information of the equipment is included, such as the manufacturing location, energy cost, production method, serial number, batch, and all relevant manufacturing process details. Finally, hash D encompasses information about the equipment registration, including the registration number, equipment category, registration location, patent registration process with the relevant authority, and other information related to the equipment's registration. Figure 4 includes the information from stages 3 to 5 of the process, starting with hash E, where the certification of the ENCE label is requested. This step is crucial because all manufacturers/suppliers wishing to apply for the PROCEL Seal for their equipment must already have the ENCE label on that equipment. In hash E, all the necessary documentation for certification is provided and, at this point, blockchain begins to interact between distinct actors: the company represented by the supplier/importer and INMETRO, responsible for reviewing the application. In hash F, information

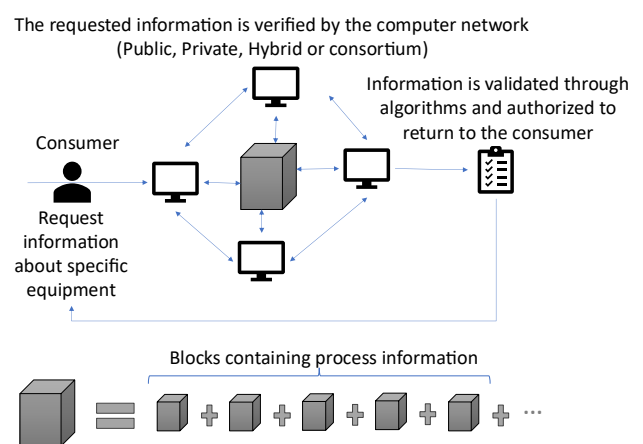


Figure 2. Summarized structure of the blockchain used in the study. Source: Own elaboration.

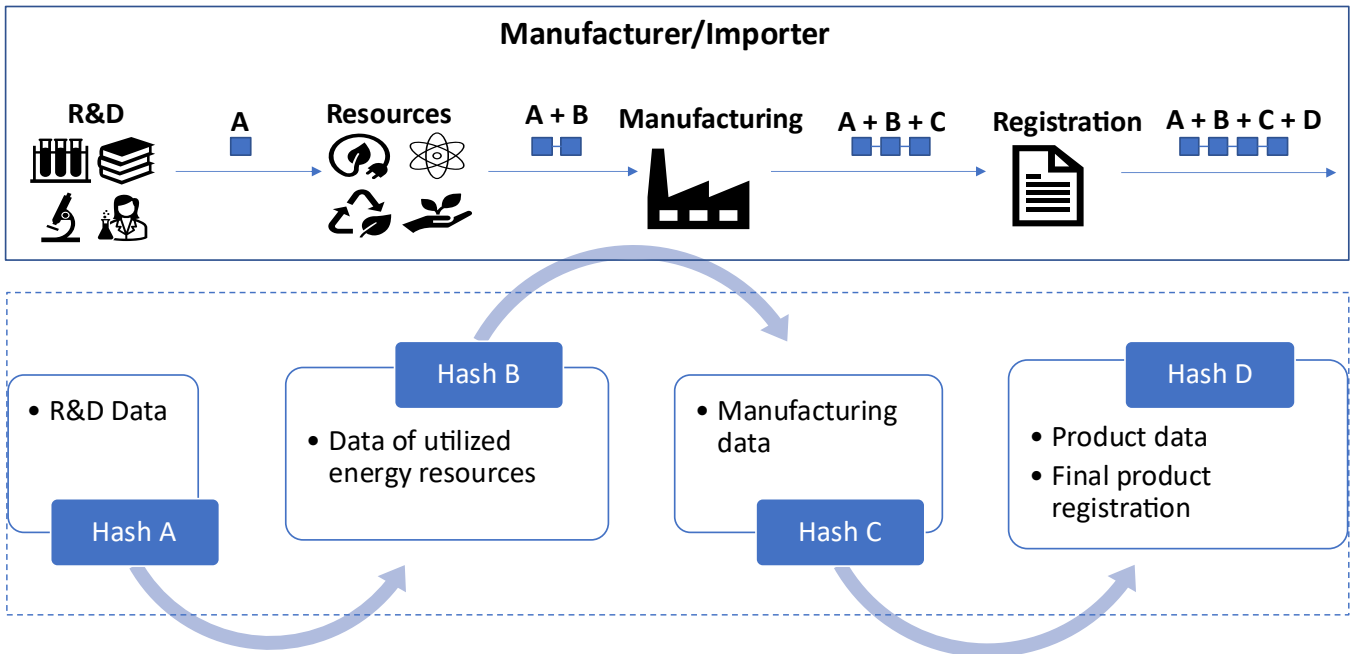


Figure 3. Stages 1 and 2 of the PROCEL Seal granting process and the blocks of information for each stage being inserted. Source: Own elaboration.

about the results of the analysis of the documentation provided by the supplier/importer is recorded.

Hash G contains the results of the audit of the supplier/importer's quality management system (QMS), if required for certification. Hash H includes information related to laboratory tests, such as test plans, sampling for testing, the laboratory where the tests will be conducted, and the test results. At this stage of the process, when the tests are conducted, blockchain can play a significant role, as discussed in the literature [12]–[16].

It can serve as digital calibration certificates, metrological traceability, smart contracts, and conformity assessment. In hash I, the conformity certificate for the ENCE label of the equipment is issued. After this step, the supplier/importer is allowed to affix the ENCE label to the requested equipment models.

Figure 5 depicts stages 5 to 9 for obtaining the PROCEL Seal. In hash J, the supplier/importer initiates the request for the granting of the PROCEL Seal for a model of equipment that already holds the ENCE label certification. During this phase, the supplier/importer submits the necessary documentation for

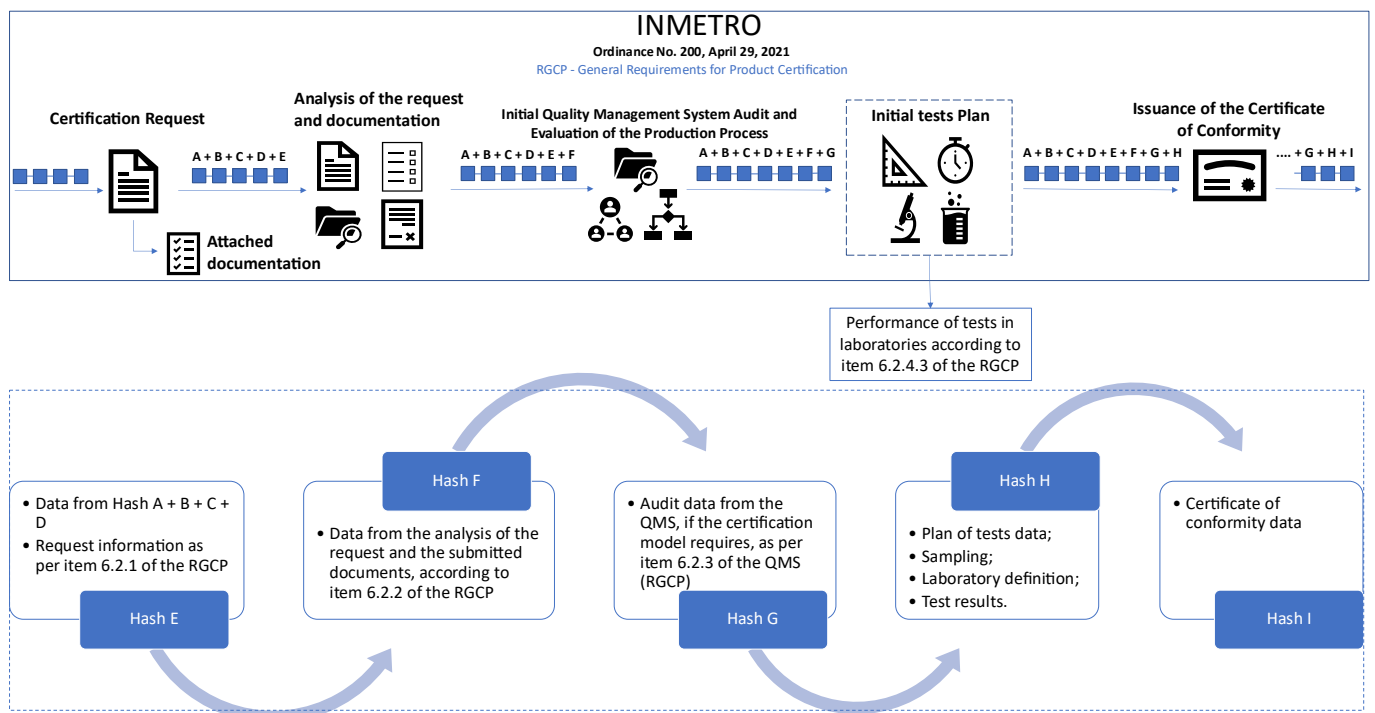


Figure 4. Stages 3 to 5 of the PROCEL Seal granting process and the information blocks for each stage being inserted. Source: Own elaboration.

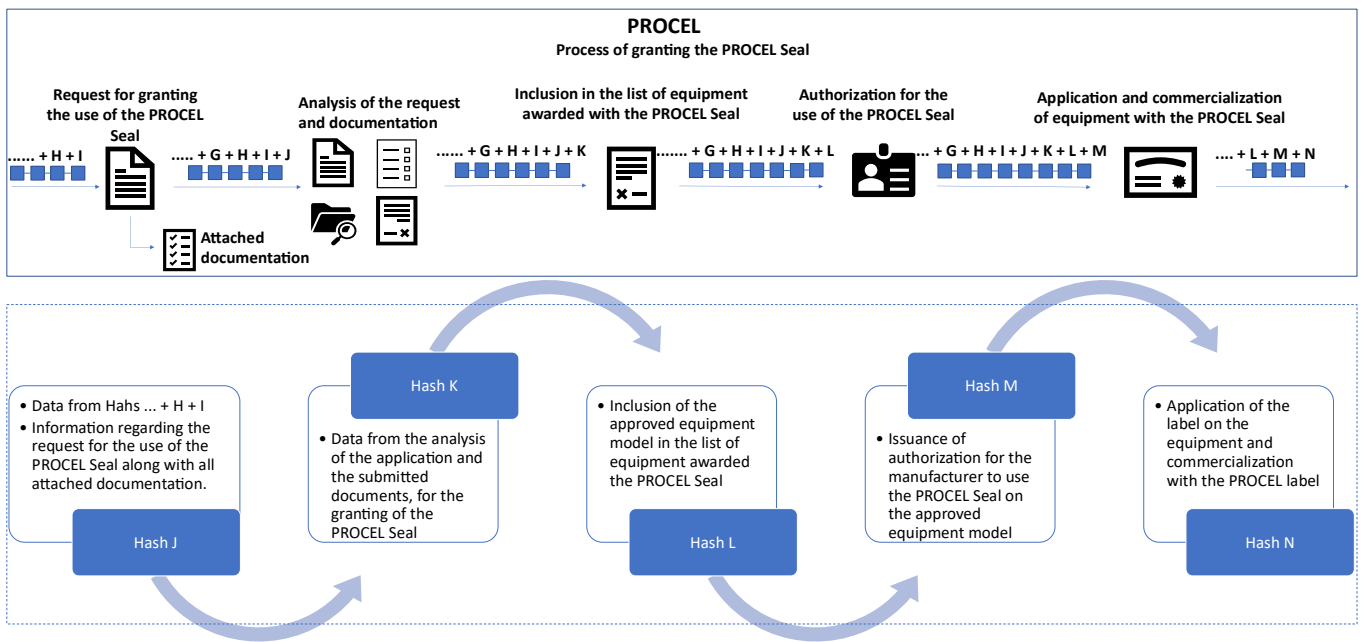


Figure 5. Stages 5 to 9 of the PROCCEL Seal granting process and the information blocks for each stage being inserted. Source: Own elaboration.

the request along with the request itself through hash I. Next, the blockchain interacts with another actor, PROCCEL. In hash K, PROCCEL conducts a comprehensive analysis of the request along with the digitally submitted documents. In hash L, after reviewing the request and documents, PROCCEL adds the requested equipment model to the list of equipment covered by the PROCCEL Seal. Hash M indicates the authorisation granted to the supplier/importer to use the PROCCEL Seal for the evaluated equipment model. The final hash in the process to be included in the blockchain is hash N, where the PROCCEL Seal is affixed to the requested equipment model, allowing it to be offered for sale with the PROCCEL Seal. Subsequently, consumers seeking information about the PROCCEL Seal on the equipment can have confidence in the presented information due to the use of blockchain throughout the entire process chain, as well as the assurance that the product is genuine.

In the context of the PROCCEL seal, blockchain can transmit the entire life history of the equipment, including the steps it went through until it reached the hands of the consumer. As a result, the consumer can trace and verify the results of the tests to which the equipment was subject to, make comparisons between different equipment, understand the ecological impact of the product's development, and ensure that the product bearing the blockchain-enabled PROCCEL seal is not counterfeit.

By implementing blockchain in the framework of the PROCCEL seal granting process, the actors involved, especially the consumer, will have access to all necessary information, with countless possibilities for additional data aggregation. This includes information on the ecological impact of the product during manufacturing, the manufacturing location, the company responsible for manufacturing and product registration, manufacturing date, serial number, warranty details, manuals, authorised technical support network, safety test performance, product certifications, as well as efficiency data and the PROCCEL seal, among others.

4. CONCLUSIONS

Labels, tags, or energy efficiency seals are essential to achieve significant energy conservation levels. They are a tool present in numerous countries and drive the competitiveness for increasingly efficient products. Blockchain technology is increasingly integrated into productive sectors and processes across various fields, including product certification.

This study proposed a smart labelling system using blockchain in the certification process chain for the PROCCEL seal. It demonstrated great potential for agility, transparency, security, interoperability, suitability, reliability, and traceability. Blockchain will soon become part of our daily lives thanks to its diverse range of applications.

As a recommendation for future work, this research envisions a more in-depth, detailed, and classified exploration of blockchain usage in product certification processes. This includes identifying blockchain functionalities used at each stage, as well as an in-depth exploration within the scope of the ABNT NBR ISO/IEC 17025:2017 standard - General requirements for the competence of testing and calibration laboratories. Moreover, the practical implementation of the model proposed in this study was not feasible within the present research. Therefore, it is recommended that future studies conduct such an application to provide a more comprehensive demonstration of the benefits, challenges, and potential improvements associated with the use of blockchain in energy efficiency certification processes.

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