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Efficient and Secure Strategy for Energy Systems of Interconnected Farmers' Associations to Meet Variable Energy Demand

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Abstract: Since ancient times, agriculture has been one of the most important resources of national development. At a national level, clean energy is a strategic objective of Romania, in accordance with the EC directive 2016/30.11.2016 ("Clean Energy for All"). At a European level, the European Commission published in January 2019 the "Towards a Sustainable Europe by 2030" strategy, highlighting the strategic importance of the Internet of Things (IoT) and blockchain technologies. In this context, the synergy between the energy management of a hybrid energy system and blockchain technology, applied to farmers' associations, represents a priority research direction in the field of information and communication technology, blockchain, and security. This paper presents the integration of the management of the energy produced by photovoltaic panels owned by farmers' association, to support the variable energy demand (necessary for water pumps, charging stations of the electric agricultural machines, the animal farms, and the auxiliary equipment) based on the IoT, DLT, blockchain technologies and smart contracts applied to farmers associations registered as users of the SmartFarm platform.

Keywords: blockchain technology; energy management; farmers' associations

1. Introduction

Worldwide, since ancient times, agriculture and its sub-sectors have represented one of the most important resources of national development.

The Agency for Financing Rural Investments has granted 32 financing contracts worth 22.7 million euros to farmers' associations in Romania, under several sub-measures within the National Development Program 2014–2020 (PNDR 2020).

The new "Energy Strategy of Romania for the Period 2014–2030, with an Outlook to 2050" has a strategic objective the Clean Energy Package, in accordance with the EC directive 2016/30.11.2016 ("Clean Energy for All"). At present, the technology of electric or hybrid agricultural machines is constantly expanding (TAGRO, the first Romanian electric tractor). In January 2019, the European Commission published the strategy "Towards a Sustainable Europe by 2030", highlighting in chapter 3.2.1 the future strategic importance of disruptive digital technologies, such as the Internet of Things

(IoT), or blockchain [1]. In this context, the synergy between the energy management of a hybrid energy system and blockchain technology, applied to farmers' associations, represents a priority research direction in the field of information and communication technology, blockchain, and security.

Khatoon et al. [2] presented in detail the potential applications and benefits of using blockchain technology in energy efficiency. They also illustrated two case studies as possible blockchain applications and presented a smart contract for energy-saving. In conclusion, future policy and regulatory models are needed in the upcoming energy efficiency market.

Yu-Pin Lin et al. [3] show a model for blockchain infrastructure in Information Communication Technology (ICT) in the agricultural system. This application helps farmers gain access to agricultural services.

The design of IoT blockchain-based smart agriculture was studied by M. Shyamala Devi [4], who used IoT in all smart applications with the goal to improve the performance of the applications in real-time. They propose design architecture for smart agriculture.

Jun Lin et al. [5] present a perspective based on IoT and blockchain that involves a smart agriculture ecosystem. Automated recording and manual recording are replaced by IoT to effectively reduce the intervention of humans in the system.

A. Rabadiya Kinjal et al. [6] use a Node MCU board with a microcontroller with a built-in Wi-Fi module. This system (IoT and cloud) gives workers real-time data, based on which they can make decisions related to the irrigation of the crops. The remote analysis is ensured by the IoT integrated into the "Smart Irrigation Analysis".

S. Umamaheswari et al. [7] present another perspective for the blockchain implementation, respectively the buyer—seller/source—destination relationship. They want to facilitate the procces of selling and buying land and crops by building a smart contact. Blockchain implementation would help especially with streamlining communication and provide instant data related to: demand and sale price, soil moisture, payments, climate environment related data, seed quality etc. to the farmers.Miguel Pincheira Caro et al. [8] present a fully decentralized AgriBlockT with the traceability for Agri-Food management. They have developed two use-cases on Hyperledger Sawtooth and Ethereum. Their performance has been compared and evaluated, highlighting the cons and pros.

Hang Xiong et al. [9] examine the applicability of blockchain in smart farming, agricultural insurance, food supply chains, transactions of agricultural products from practical and theoretical perspectives. Furthermore, it presents the challenges in creating an ecosystem in utilizing blockchain technology in the food and agriculture sector.

Gaesejwe Bagwasi and Chinnamuthu Chinnaperumal Raja [10] present the expansion of the blockchain and digital technologies in the food and agriculture sector, contributing to stopping food fraud, affirming legitimacy in agriculture commodities, and promoting food safety. The factors that influence the efficiency of the blockchain are constancy, lucidity, decentralization, and security.

Andreas Kamilaris et al. [11] discuss blockchain technology and the maturity level that it reached in developing a transparent food supply chain. They also provide an in-depth analysis of the challenges in this endeavor, such as policies, technical aspects, regulatory framework, governance, and accessibility.

Oscar Bermeo-Almeida et al. [12] present a systematic and clear overview of transaction times and food safety in agriculture. The database is built on research results from 2016 to 2018, attesting to the novelty of the subject. The results show that 60% of the papers are on the food supply chain. The main concern is on the IoT for blockchain technology.

Vinay Surendra Yadav and A. R. Singh [13] research blockchain technologies from the safety angle, connected with the information system, traceability of the provenance, finance, insurance, crop certification, and agro-trade. The study also analyses the trends in various countries that aspire to increase the use of blockchain technologies in agriculture.

Xiaohong Li, Daobao Wang, and Maolin Li [14] investigate the blockchain in agriculture, analyzing its faults and challenges. They implemented the systems in five villages and compared and analyzed the sustainability of electronic agriculture and its benefits for the farmers. An average of 25% increase in sales has been reported.

New agricultural technologies currently researched and applied, one of them being the blockchain and IoT. In the last years, multiple applications and strategies have been tested to provide the best experience for the farmer, but also for the customer. These solutions are analyzed to improve efficiency, communication, and security, to provide sustainable digital agriculture, to increase sales, and to improve agricultural products. Smart applications are continuously being developed for better performance and efficiency and updated to the trends of the other countries.

The case study offers the possibility of implementing smart contracts based on blockchain technology dedicated to farmers' associations that have the possibility to trade the energy produced by photovoltaic panels, obtaining tokens, in return. The tokens will be used for the purchase of the energy needed for water pumping systems for irrigation, as well as for charging stations installed on the farms, where electric agricultural equipment is charged, including auxiliary electrical equipment, energy for animal farms. This implies eliminating intermediary companies, having a lower energy price, increasing the number of farmers' associations, and promoting Green energy.

The proposed solution is to create a platform for energy management based on IoT, blockchain, and smart contracts for farmers' associations. The platform ensures:

- The transaction for the sale of the energy produced by the photovoltaic panels (PV), installed in the farmers' associations on the arid lands, located on the irrigation systems channel or on the roofs of the animal farms;
- The purchase transaction with tokens. The farmers use tokens to buy the energy required to supply the water pumps from the irrigation systems, the charging station that powers the agricultural electrical equipment, and the farm facilities;
- Monitoring the amount of energy produced and consumed;
- Monitoring the transactions with tokens.

The novel elements of the project proposal are highlighted as follows:

- Smart blockchain contracts for energy management in farmers' associations eliminate intermediary transactions, being transparent, encouraging the formation of partnerships, in addition to optimizing processes in farmers' associations;
- Integration of DLT technology for farmers' associations to ensure the transparency of the energy marketing process and the storage of data in immutable databases;
- Implementation of tokenization and development of an internal economy within farmers' associations according to the European Directive 2018/843/EU, and the ERC20 and ETC721 standards based on the Ethereum blockchain;
- Integration of smart meters in a software package for the automatic energy management in farmers' associations.

This research is structured in five sections, starting with the introduction, where the literature of the blockchain is reviewed at the current stage, followed by the material and methods part were the platform for energy management with IoT, smart contracts and blockchain, and the sectors it can be applied to, as well as all novel elements that the paper brings. The third section of the paper presents a case study and introduces the main modules: Backend mode, mobile application, etc. The fourth part details the implementation of the application and its operating principle, presenting samples of data from the operating stages, and finally capitalizes and discusses the obtained results. The last part includes the main findings of this research and highlights the benefits of the proposed energy management platform for farmers' associations.

2. Blockchain Implementation in Multiple Domains

Blockchain technology represents the future of development and improvement in all the domains. This technology has multiple advantages, but the most important one is that it improves the quality of life for all the people involved in the industry and provides more qualitative products and services. The implementation of blockchain technologies has expanded over the last years, and the results are even more promising. The following section covers the sectors of agriculture, automotive, smart city, energy, tourism, health, water, industry, public administration, logistics, and supply chain.

In the Automotive domain, the problem consists in the fact that the network of charging stations, is at present, limited in the number of devices. Currently, there are multiple payment methods for each charging station network, and a user will have to use multiple RFID cards and applications to recharge the vehicle. The solution is to adapt the application to manage charging stations, and to implement blockchain transactions that unify the multiple available payment methods.

Ali Dorri et al. [15] present blockchain as a solution in the automotive field. Problems for smart vehicles, such as privacy threats, security failures, remote hijacking, etc., can be solved. In order to increase the security and the privacy of the user, they implement a blockchain based architecture. The efficiency of the system is ensured by updates on the wireless remote software and other services.

Pradip Kumar Sharma, Neeraj Kumar, and Jong Hyuk Park [16] propose a blockchain distributed framework for the automotive industry, meant to address issues related to manufacturing, maintenance services, insurance, government regulations, etc. The proposed solution includes a miner node selection algorithm, and as the authors attest, the model proved its feasibility and wide applicability range.

Paula Fraga-Lamas and Tiago M. Fernández-Caramés [17] analyze the current status of the involvement of blockchain in the automotive industry—a technology that can address issues related to authentication, transparency, integrity, trustworthiness, robustness, traceability, privacy, security, anonymity, etc. The study proves the applicability and sustainability of blockchain technology.

Parth Singhal and Siddharth Masih [18] present blockchain in the automotive industry from the perspective of efficiency and scalability, which raise significant concerns. The research offers solutions to the presented problems and illustrates the use of blockchain as cost-effective, efficient, and scalable.

Christian Kaiser et al. [19] research the problem of the privacy level on vehicle data on the continuously increasing automatization. They associate blockchain technology with decentralization, trust, and transparency. They offer the concept of OVDP (Open Vehicle Data Platform) to provide security and privacy to the user.

The automatization in the automotive area improves performance and efficiency, but also highlights problems in the privacy and security department and involves changes in manufacturing, maintenance, insurance, and government regulation. The solution appears to be blockchain technology because it helps with scalability, transparency, costs, integrity, traceability, anonymity, etc.

In the Smart City domain, the problem is represented by the low development of intelligent parking lots, various payment methods for parking, rental of mobile vehicles, such as bicycles, scooters, drinking water, and transport infrastructure. The *solution* is to adapt the application to manage parking, transport and drinking water supply, and respectively, scooter management.

Kamanashis Biswas and Vallipuram Muthukkumarasamy [20] present various technologies, such as interconnected networks, smart cities, cloud computing, and IoT, that can provide better services and higher efficiency.

Jianjun Sun, Jiaqi Yan, and Kem Z. K. Zhang [21] propose a framework based on an economy sharing perspective and three dimensions: Organization, technology, and human. They analyze how these three factors are going to be improved by blockchain technology in a smart city with the capability of sharing services.

Alessandra Pieroni et al. [22] work to improve people's lives in smart cities with the help of the data collected from the users operating sensors, IoT devices, wearable devices, and so on. The implementation of these elements would improve the life of the citizen. Upgrading a smart city to off-grid is more efficient with the help of Blockchain technology with the help of blockchain technology, which would be used to sell/buy energy, exchange information, etc.

Kichan Nam et al. [23] propose a smart city/tourism framework, presenting its essential characteristics. They expect that this proposal will evolve and will influence the tourism industry, progressing towards smart city tourism.

Haiyang Yu, Zhen Yang and Richard O. Sinnott [24] analyze the vulnerability of the TPAs (third party auditors), which are subject to numerous security threats. The proposed solution for smart cities is blockchain-based on a decentralized big data auditing scheme. The authors evaluated this solution from a theoretical and an experimental perspective.

Smart cities are the next step in evolution and their efficiency depends on the performance that they offer through security, integrity, trends, innovation, services, etc. At this level, blockchain technologies are seen as solutions to secure the life of the citizen. The new concept of smart city tourism may be the next niche on the evolution of the tourism industry.

In the Energy domain, the problem is related to the decentralization of the energy system (DER). The solution is to adapt the application, to encourage the adoption of peer to peer energy solutions.

Gijsvan Leeuwen et al. [25] present an energy management platform based on blockchain with a bilateral mechanism. They use the algorithm ADMM (alternating direction method of multipliers) to fix the problem of distributed optimization. Results show that, in comparison with baseline scenario, the cost is reduced by 34.9% for the entire community. Eung Seon Kang et al. [26] propose a trading market for the renewable energy that is produced in a smart house. The transaction is generated by blockchain. To provide the security of the energy trading, the Ethereum smart contracts are inserted in the microgrid.

Mohamed Amine Ferrag and Leandros Maglaras [27] present a five phase blockchain scheme with hash function and short signatures. The system was implemented on three sources: A web robot (Bot)-IoT dataset, a power system dataset and the CICIDS2017 dataset.

Claudia Pop et al. [28] analyze the system from the perspective of collected information from IoT and work to balance the supply and demand. They also propose the Ethereum platform and prove that the system can be used for smart grid balanced quantity of energy between production and demand. Amanda Ahl et al. [29] explore the challenges that may appear on the blockchain microgrids and identify solutions for this issue. The platform involves five dimensions: Economic, technological, social, institutional, and environmental. This paper aims to expand the blockchain institutional arch over to the energy field.

The blockchain implementation in the energy sector seems to be a necessary measure to overcome the potential flaws and errors. The main purpose of blockchain implementation is the mélange between various dimensions, such as institutional, environmental, social, economic, and technological. The implementation of different platforms and schemes can help with the balance between the energy supply and demand.

In the Tourism domain, the problem consists in the diverse payment and access methods for various services in cities or tourist areas. The solution is adjusting the application to unify payment and access methods.

Umesh Bodkhe et al. [30] present the problem of potential attacks and failures in the system of airports, cruises, travel agencies, railways, hotels, local taxis and restaurants. They propose the platform BloHosT (Blockchain Enabled Smart Tourism and Hospitality Management). It is interactive and allows tourists to initiate payments. This platform provides a higher ROI (return of investment) in comparison with the classic methods. Davide Calvaresi et al. [31] bring in discussion the frailty of reputation and trust in the field of tourism and what the implementation of blockchain technologywould mean. They present a review over the results of BCT in tourism, highlighting its challenges and advantages.

Irem Onder and Horst Treiblmaier [32] highlight the presence of cryptocurrencies and blockchain in the financial area and its extension to the tourism field. The article proposes a discussion on the blockchain field and provides three high-level propositions for further interventions and improvements.

Gavina Baralla et al. [33] propose blockchain as a tool meant to prove transparency in smart food tourism. Their other purpose is to increase the local economy providing easy access systems, reliability on the market chain, better selling strategies and products originality and traceability. Ali Ihsan Ozdemir, Ilker Murat Ar. And Ismail Erol [34] research work is based on the following perspectives: The use of crypto currency, blockchain platforms, tokens, blockchain governance model and smart contracts. They bring into discussion the DAPPs (distributed applications problems).

The most searched characteristic that blockchain technology provides for the tourism field is transparency. This feature brings value to the service offered to the customer and improves the income of the provider. Local economies will grow and tourism will have a higher quality.

In the *Health* industry, the *problem* consists of the doctors' and patients' lack of access to a database with relevant information concerning treatment and treatment results for similar prior diagnosis, support for the pharmaceutical industry for medicines production. The *solution* is adapting the application to creating the diagnostic database, including prescribed medication, treatment results and management of the pharmaceutical industry, in correspondence with the identified needs.

Sudeep Tanwar, Karan Parekh and Richard Evans [35] present blockchain technology in the medical sector as an improvement in different areas, underlining its multiple advantages, such as: Improved insurance billing, better medical records, secure data access, smart contracts and distributed database, device tracking, hospital assets, prescription databases, and so on. This is a major benefit in correctly treating a patient. Yi Chen et al. [36] bring a new solution to provide the full medical records of a patient using blockchain technology. The article presents the differences between the classical system and the new one, which upgrades security and storage, proves verifiability, decentralization and immutability.

Kristen N. Griggs et al. [37] open the discussion about the security level of the data. They propose the blockchain-based smart contracts as a solution to this problem. This would help with the management and secure analysis of medical sensors. The Ethereum protocol is introduced so that t5he events stored in the blockchain could by smart contracts specifically defined for smart devices. This way, the vulnerability issues of the system would be addressed.

Asma Khatoon [38] reviews the literature over the blockchain applications in the health system. She analyzed the data management and the way it can be improved. The Study compares multiple medical workflows and facilitates the search in the field. Harleen Kaur et al. [39] present the issues of processing and storing medical data. They highlight the usability of the cloud environment and blockchain technology and propose combining them to develop new applications in the healthcare sector. This would reduce the failures in the security system, reduce costs and increase data accuracy.

Blockchain technology in the healthcare system is a novelty in the security level, costs, data accuracy, patient privacy and so on. For system failures there are different solutions that the researchers are analyzing and applying. Blockchain provides unlimited access, data storage, verifiability, decentralization, security, and full records.

In the *Water* domain, the *problem* is represented by the reduced quality, and costs for the consumer by lowering the energy price. The *solution* is adapting the application to obtain a higher quality water and at a lower price by using green energy.

Borja Bordel et al. [40] address the water crises in the areas where the economy is directly affected by agriculture. They propose to support the management of these situations in the irrigation communities with blockchain technology. They implemented this system and presented its performance.

Eustace M. Dogo et al. [41] present the combination of blockchain and IoT on the water management. They analyze the feasibility of the system in different cases, such as water quality monitoring and stormwater management. The information is directly distributed to the consumers and other stakeholders. They present socioeconomic gains, technical advantages, transparency, security, overall efficiency, reduced operational cost being further explained.

Usman W. Chohan [42] considers the development of the blockchain management in California. The article presents the implementation of blockchain technology in sustainability projects and environmental protection. The project was studied on the water management blockchain of IBM. Can Dang et al. [43] present a market structure which concentrates on the load management. The load is more accurate under the blockchain-based market and the cost is reduced by 18.9% compared with the classical version. Seung Jae Pee, Ju Wook Jang and Jong Ho Nang [44] implement smart contracts to enable fast payment and delivery confirmation. Blockchain provides transparency and immutability using participating nodes. The control Geth of the system is provided through a web server, Node.js.

The water system has some issues that can be solved or improved using blockchain technologies. These technologies can provide a better accuracy and help in the areas where the system is not adequately administrated.

In the *Public administration* domain, one of the *problems* is the poor voting system. The *solution* is adapting the application for creating a voting system that rules out any fraud suspicion, ensuring a transparent voting and vote counting process. Merrill Warkentina and Craig Orgeron [45] present the multiple advantages of blockchain technology. It ensures regulatory implications, governance, and security for the government. They use CIA (confidentiality-integrity-accessibility) to create advantages for public managers.

Parol Jalakas [46] highlights the benefits of blockchain implementation as new governance forms, discounts in the transaction costs, provides a more valuable e-governance and a better e-service. The main purpose is to increase efficiency in the public sector and to provide a base for future researchers.

Muhamed Turkanovic et al. [47] propose to use blockchain technology to create a decentralized environment in the educational field, any data and transaction being recorded in a public ledger in a verifiable and permanent way. The EduCTX platform is a higher education credit platform meant to provide a more transparent and technologically advanced education system, offering a globally unified viewpoint for students, higher education institutions and other interested organizations and companies.

Horst Treiblmaier and Christian Sillaber [48] address the subject of public administration and the unbalance between the workload and existing resources. They present a case study revolving around the business of building and modifying cell towers. This research presents advantages and disadvantages of blockchain technologies in the public administration and a collection of best practices. Hissu Hyvärinen, Marten Risius and Gustav Friis [49] assess a feasible solution for illegitimate tax refund claims, after blockchain technologies are applied to the financial market. This system is implemented to increase transparency in the flow of dividends and reduces tax fraud.

The blockchain in public administration opens new gates with respect to the level of transparency and development in multiple departments, among which we recall the education, business, and public sectors, followed by many other fields. Blockchain technologies are the new solution to corruption, discontinuities, and other issues in the systems.

In the *logistics and supply chain* domain the main problems are the lack of transparency, traceability and supervision. The solutions are the increase of the digital technology use and to provide more transparent systems.

Shiaofang Liang, Mingchen Li and Wenjing Lib [50] present the blockchain in the logistic service transactions using a traceability algorithm. They analyzed the issues of the classic supply chain service and propose a novel concept. Standardizing the physical products using Globe sandara 1, based on logistics service supply, they propose a traceable data model.

Jiafeng Li et al. develop the Ethereum [51] platform to provide an irrevocable, transparent and open blockchain which is combined with a RRS ERM– Responsibility Relay System and Evaluation and Reporting Mechanism. After multiple empirical analyses have been observed the following advantages: Improving the public welfare of charitable donations, due to the increased quality of philanthropically raised materials, enhance the system's cleanliness coefficient and increase the user's trust in the project.

Kristjan Kuhi et al. [52] highlight as main objective the performance improvement. They evaluate the PMS (performance measurement system) for the logistic industry from the feasibility perspective. The performance of the supply chain performance in the resent is limited by the restraining of innovative digital improvements, the lack of transparency, transaction costs and limited throughput. There have been identified and validated new indicators to increase the trustworthiness and the visibility of the decision making process.

Ming Li and G.Q. Huang [53] present a BCWMS (blockchain-enabled workflow management system) and use three key innovative technologies to entitle it. The three keys are: The first one is used to realize the Universal Plug and Play management, the second one is for the logistic resources coordinate and the third one is to provide data reliability for the higher decision making customers.

Mamoona Humayun et al. [54] explore the blockchain and IoT technology in transportation and smart logistics. They propose a BCTLF framework to implement an intelligent system. In the research are implemented two real life blockchain and IoT in transportation and logistics.

Huma Pervezand Irfan Ul Haq [55] present the disruption in the business processes when the cloud, IoT, and blockchain are going to be introduced. This paper researches the logistics area and brings up the positive impact over the KPIs (key performance indicators) and their characteristics.

Yonggui Fu and Jianming Zhu [56] propose the blockchain as a solution for the lack of traceability and supervision in the intelligent logistics system. They present the applying scheme, operation principle and the mechanism for authentication, storage and access. They archive to improve the supervision operation and the efficiency.

Niels Hackius and Moritz Petersen [57] identified that blockchain is used by some companies to unify industry through consortia, build new business modes and drive digital transformation. The limitations that they meet are the long term uncertainties and lack of technology usability. This article constitutes a base for the theoretical and practice managerial guidance.

The blockchain implementation in *industry* comes with the need of improved monitoring and maintaining systems, increased security and privacy, better economic and financial models and new business directions. The solutions consist in a higher number of implementations, develop new paradigms and introduce the customers, logistics and production companies in the decision making process.

Weilin Zheng et al. [58] provide blockchain service for smart contracts analysis and testing and system monitoring and network developing over the cloud computing environments through BaaS platform. The developed platform name is NutBaaS and has the capability of monitoring and maintaining the system.

Joseph E. Kasten [59] proposes a review over the blockchain in manufacturing activities and engineering activities. He highlights that this area of applicability splits in three essential samples: To increase the efficiency of the manufacturing process, to enhance inter and intra-organizational communications and to protect data validity. The goal of this paper is to build a base for further theoretical and practical research.

Youyang Qu et al. [60] built a decentralized paradigm using blockchain jointly and federated learning for D2C (big data-driven cognitive computing). The advantages of the federated learning are that the process will be more efficient, because blockchain technology assures incentive mechanism and the privacy protection issues are solved.

Toqeer Ali Syed et al. [61] present a comparative study of the applications and fundamental concepts of the core blockchain architecture in three main domains: Business and vehicular industry, healthcare and Internet-of-Things. The distinctively discussed challenges and solutions were proposed by the industry and the research community. The paper also contains analysis over multiple blockchain platforms with their applications and consensus models.

Donghang Lu et al. [62] review the counterfeiting in the supply chain and highlight the millions of dollars of lost revenue. They develop a system to build prevention in the automotive supply chain. The blockchain implementation would help with facile tracking of goods and privacy enforcement.

Tiago M. Fernández-Caramés and Paula Fraga-Lamas [63] examine the challenges and benefits of the smart contacts and blockchain in the applications development of Industry 4.0. The main objective of the article is to provide a guide for future developments in the Industry 4.0 in determining the next step in the cybersecurity industrial application.

Almero de Villiers and Paul Cuffe [64] provide a new disruption framework for blockchain in the electricity industry. This is a three-level concept that may be able to shift the face of an industry entirely. Is important to analyze the taxonomy in existing research to build a new one. There are also discussed the application of multiples ideas in industries and the way that the industries are disrupted or affected.

Tejasvi Alladi et al. [65] investigate the commercial implementation in multiple domains. They discuss the challenges for each of them and the blockchain implementation in Industry 4.0 issues. This article constitutes a base for further research in the area and helps the decision makers in the process of blockchain technology investment and implementation in frame of the Space Industry 4.0 based on the Industrial IoT (IioT).

Umesh Bodkhe et al. [66] propose a review of multiple solutions based on blockchain in various applications from the Industry 4.0. They conclude the paper with a comparison based on multiple parameters of the advantages and disadvantages of the traditional security solutions.

Jameela Al-Jaroodi and Nader Mohamed [67] investigate the benefits, opportunities and challenges of implementing blockchain technology in various industrial applications, as well as the requirement that the incorporation would take. To archive a better efficiency of blockchain technology is necessaire to overcome the challenges that may appear.

Tomaso Aste et al. [68] present the implementation of blockchain in industry and society from the financial view with security elements and development possibilities. They analyze its opportunities and challenges from its base; the bitcoin digital cash system to the current applications.

Hongfang Lu et al. [69] present the theories regarding blockchain technology implementation and how it's implemented in gas and oil industry from the following aspects: Cyber security, supervision, management and decision making and trading, the risks, opportunities and challenges that rise. Their conclusions refer to the poor number of applications of blockchain in this industry and the need for improved efficiency and transparency.

Yulei Wu et al. [70] investigate the IoT in the Industry 4.0 and the edge computing and blockchain paradigms. They work to provide an actual perspective over the scalability, privacy and security of IoT/IioT critical infrastructures.

Yan Cao et al. [71] analyze the implement of blockchain to provide efficient product traceability and information security. In the steel industry, blockchain technology is implemented using participation from the consumers, logistics and production companies. This would help with product perception, complete information delivery and increased effectiveness.

2.1. Blockchain Implementing

Blockchain technology improves the results of the applications in all the sectors (Figure 1) it is applied to. The benefits of blockchain implementation may be observed in the results of multiple studies and applications. Combined with IoT, this technology may find a wide range of solutions to all the issues that could emerge. Researchers are identifying proper means to approach the new errors and problems that arise daily. The continuous communication between the customer and the provider ensures more accurate information and builds precise databases for further research.

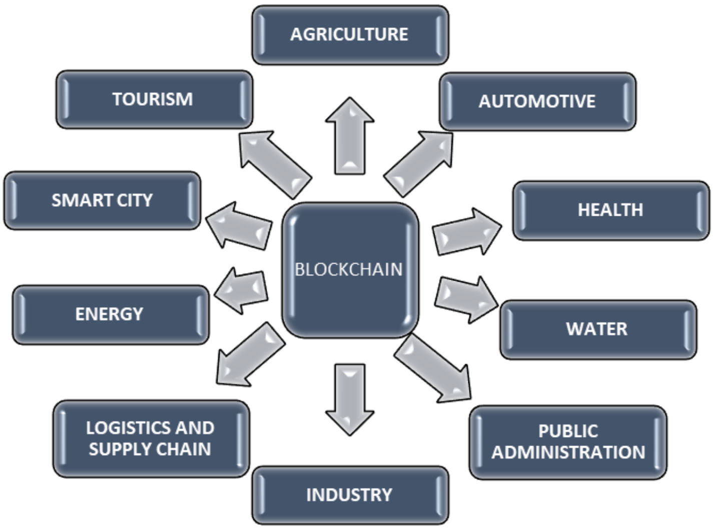

Figure 1. Blockchain implementation sectors.

2.2. Results of Blockchain Implementation

Every domain has issues and flaws, so to evolve, it is necessary to revise and improve all the areas of our lives. In this research, we provide a wide range of results obtained after the implementation of blockchain technologies.

In agriculture, the objectives of blockchain implementation were to increase energy efficiency, facilitate access to services, increase performance, introduce machines, enlarge the applicability range, realize theoretical and practical products for this area, and to help with safety, traceability, finance security, certification, and evolution. Along with these results, there were performances regarding food fraud limitation, transparency in the supply chain, food safety, sustain agriculture digitalization, economy, and assure the workers' comfort.

In automotive, we identified problems on the customer security branch and applicability range, but they were solved. Not just the security and privacy were increased, but also the services become more cost-effective and transparent, increasing the customers' trust.

By analyzing the smart cities, we can present organization, technology, life quality, evolution, and development as the mainly-improved features the services quality. The performance increases may be observed through the number of offered new facilities and the reduced issues in the system.

The goals of blockchain in the energy sector were archived, and now the pee—to-peer energy solutions, reduced costs, and security increases are provided. The performance in this field is given by the balance between supply and demand and high scale applicability.

Regarding the health system, the raised issues were connected with the precision of the databases, medical records, and system failures. In regards to the health system, there are commonly raised issues about the validity of the medical records stored in classic databases, data privacy, security concerns, system failers and others. With the help of blockchain technology and decentralization, some of these concerns were addresses and innovations and upgrades were achieved n areas such as the validity of medical data, management and access to medical records, anonymization, auditing and others.

In the water domain, the main objectives are energy price diminutions, consumed quantity of water, and load accuracy. The performances, reached through blockchain implementation in this field, are the following: Socioeconomic gains, technical advantages, transparency, security, overall efficiency, reduced operational cost, sustainable projects, environmental protection, fast payment, and delivery confirmation.

For the public administration, the goals are to provide better practices, transparency in the dividends, and reduce tax fraud. Reaching these objectives, there can be identified some positive results regarding the fraud in the voting system, regulatory implications, governance, security for government, discounts in the transaction costs, more valuable e-governance, and e-service.

In the domain of logistics and supply chain, blockchain implementation is an essential step to help with evolution and improvements in systems transparency, traceability, and supervision, increases of the digital technology usage, and to provide more efficient systems.

In the industry, blockchain implementation is essential, and it can fix multiple problems to provide more efficient systems and a larger informational database from the experimental view.

Blockchain implementation in multiple domains had different results and limitations; in Table 1 we presented the main scope and the archived performance for each domain.

Table 1. Blockchain implementation results.

Domain	Scope of Implementation	Achieved Performance
Agriculture	Energy efficiency market [2].	Stopping food fraud, affirm legitimacy in agriculture commodities, and promote food safety [10].
	Facilitates the farmer access to agricultural services [3].	Ensures a transparent supply chain and overcomes factors, such as policies, technical aspects, regulatory framework, governance, and accessibility [11].
	Improve the performance of the application in real-time [4].	Food safety in agriculture [12].
	Effectively reduce the intervention of humans in the system [5].	Sustainable digital agriculture and sales increase [14].
	Applicability at small or large scale [7].	Improves work environment and workers are less troubled [6].
	Smart farming, agricultural insurance, food supply chains, transactions of agricultural products from practical and theoretical perspectives [9].	Better performance of the systems [8].
	Provides safety, traceability, finance security, certification, and evolution [13].	
Automotive	Unify the multiple payment methods available and increases security and privacy [15].	Cost-effective, efficient, and scalable [18].
	Feasibility and a wide applicability range [16].	Scalability, transparency, costs, integrity, traceability, anonymity [19].
	Authentication, transparency, integrity, trustworthiness, robustness, traceability, privacy, security, anonymity [17].	
Smart city	Better services and efficiency [21].	Development of intelligent parking, unifying different payment methods for parking, rental of mobile vehicles, such as bicycles, scooters, drinking water, transport infrastructure [20].
	Improvements on the dimensions: Organization, technology, and human [22].	Fixing the issues on the security system [24].
	Improve the life of the citizen and increases the market on energy and information [23].	
	Evolution and development in the tourism [24].	
Energy	Peer to peer energy solutions [25].	Balance supply and demand [28].
	Reduced costs [26].	High scale applicability [29].
	Security of the energy trading [27].	
Tourism	Higher ROI [30].	Increases trust and reputation [31,32].
	Provides high-level propositions for further interventions and improvements [33].	Transparency in smart food tourism, boost the local economy, easy access systems, reliability on the market chain, better selling strategies, and product originality and traceability [34].

Table 1. *Cont.*

Domain	Scope of Implementation	Achieved Performance
Health	Wider and more precise databases for doctors, management of the pharmaceutical industry according to needs [35].	Upgrades security and storage, proves verifiability, decentralization, and immutability [36].
	Improved insurance billing, better medical records, secure access to data, smart contacts and distributed database, device tracking, hospital assets, prescription databases [35].	Management and secure analysis of medical sensors, reduces the vulnerability of the system [37].
	Reduces the failures in the security system, reduces costs, and increases the accuracy of the data [39].	Improved data management [38].
Water	Lowering the price of energy [40].	Socioeconomic gains, technical advantages, transparency, security, overall efficiency, reduced operational cost [41].
	Reduces water crises [40].	Sustainable projects and environmental protection [42].
	More accurate load, cost reduction [43].	Fast payment and delivery confirmation [44].
Public administration	Verifiable and permanent way in the public ledger [47].	Voting system without any fraud, regulatory implications, governance, and security for government [45].
	Better practices [48].	Discounts in the transaction costs, provides a more valuable e- governance and a better e-service [46].
	Increase transparency in the dividends and reduces tax fraud [49].	
Logistics and supply chain	Completed supervision system in the process of logistics service transaction [50].	The algorithm realizes the end-to-end traceability of the logistics service supply chain, and the service transaction is transparent, while ensuring the integrity and security of the data [50].
	Achieve the consistency of the data on the chain with real-world status, as well as the authenticity and transparency of philanthropy logistics data [51].	Increases the user's trust in the project, enhance the system's cleanliness coefficient, and increases the quality of philanthropically raised materials [51].
	Improving performance [52].	Trustworthiness and visibility to management and process improvement decisions [52].
	Improvement of logistics service [53].	Breaks this limitation and achieves central coordination of logistics resources to satisfy heterogeneous requests [53].
	Exploring the potential of the Internet of Things (IoT) and blockchain technology in smart logistics and transportation [54].	
	Paradigm shift in the domains of Supply-chain and logistics [55].	Key Performance Indicators (KPIs) of the logistics domain being positively affected [55].
	Security threats and privacy leak risks in the operation process of related data of intelligent logistics system [56].	Improving the efficiency and supervision of the operation of the intelligent logistics system [56].
	Improve the information flow between the supply chain partners [57].	Drive digital transformation, constitute new business models, and unify the industry through consortia [57].

Table 1. *Cont.*

Domain	Scope of Implementation	Achieved Performance
Industry	To provide blockchain service over cloud computing environments [58].	Developers can focus on the business code to explore how to apply blockchain technology more appropriately to their business scenarios [58].
	To protect data validity and to enhance inter and intra-organizational communications. To increase the efficiency of the manufacturing process [59].	Blockchain application, such as additive manufacturing, cloud manufacturing, and building information models (BIM0s) [59].
	To fix the privacy protection issues [60].	Quick convergence with advanced verifications and member selections [60].
	The widespread future adoption of blockchain technology in major areas [61].	
	The automotive industry a platform able to distribute trusted and cyber-resilient information that defies current non-collaborative organizational structures [62].	
	To develop Industry 4.0 applications [63].	Provides a detailed guide for the future Industry 4.0 developers [63].
		A guide for engineering managers wishing to make sense of blockchain's potential in electricity [64].
	Newer application areas of blockchain technology [64].	Assists decision-makers in their blockchain adoption and investment in Industry 4.0 and Industrial IoT (IioT) space [65].
	Improve systems scalability, robustness, data storage, network latency, auditability, immutability, and traceability [66].	
	Securely recording and sharing transactional data, establishing automated and efficient supply chain processes, and enhancing transparency across [67].	Better efficiency of blockchain technology [67].
	The opportunity to generate the necessary level of trust between unknown and anonymous counterparts to allow them to trade without intermediaries [68].	
	Increase the number of applications of blockchain in the oil and gas industry [69].	Better understanding of the of blockchain technology [69].
	Fixing security and scalability issues [70].	
	To ensure information security and achieve efficient product traceability [71].	Better product perception, complete information delivery, and increased effectiveness [71].

3. Case Study: Energy Management Platform Dedicated to Farmers' Associations

3.1. Energy Management Platform Architecture

The flowchart of energy management platform architecture is described in Figure 2.

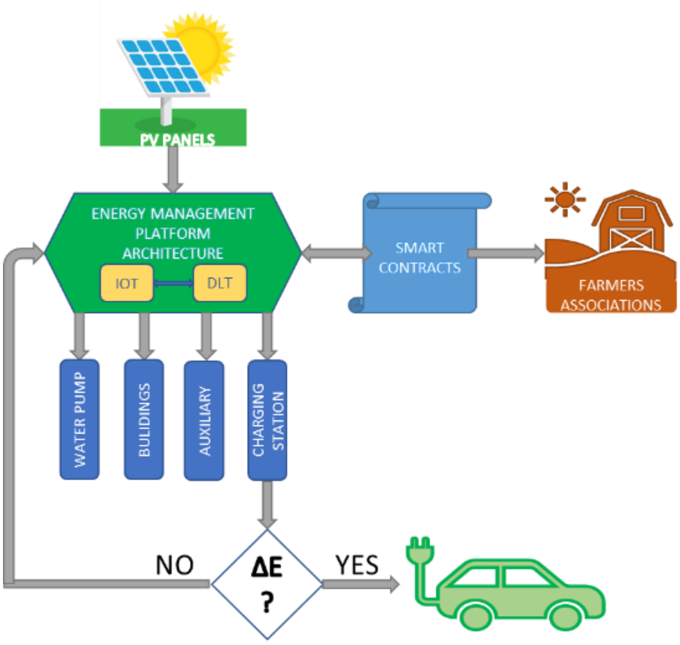

Figure 2. Flowchart of energy management platform architecture.

The most important future platform research directions are presented in Figure 3

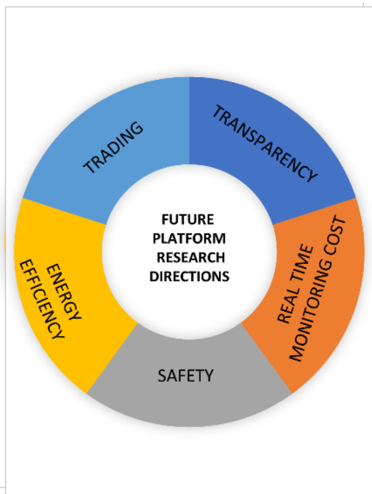

Figure 3. Future platform research directions.

- Trading—the platform offers farmers' associations that have PV fields to trade excess of energy through smart contracts or to buy from the energy market;
- Transparency—the platform offers transparency regarding the transactions made;
- Energy efficiency
- Safety
- Real-time monitoring cost

The most important features of the platform are presented in the next figure.

3.2. Innovative Character of the Application

The innovative character of the application is represented by the energetic management of the energy produced by the photovoltaic panels from the farmers' associations to support the variable energy demand (necessary for water pumps, charging stations for electric agricultural equipment, animal farms, as well as auxiliary equipment), based on IoT, DLT, blockchain, and smart contracts applied to farmers' associations, registered as users of the platform. Globally, there are similar initiatives, namely, the development of energy trading platforms in a decentralized way through blockchain, for example, Lo3Energy [72] (USA) or Power Ledger [73] (Australia), but for the time being, none of them focuses on farmers' associations. The novel elements of the project proposal are presented below:

1. Smart contracts run on blockchain for energy management in farmers' associations. Nationally, blockchain technology is not used for energy management in farmers' associations, and internationally, there are similar projects (Lo3Energy (USA) or Power Ledger), but they are oriented towards optimizing the processes of farmers' associations. The *novelty* is represented by the fact that blockchain technology will eliminate intermediary transactions, being transparent, and encouraging partnership formation.
2. Promote PV integration in farmers' associations. Nationally, only a few farms using PV have been identified, but interest exists according to the Romanian Agency for Payments and Intervention for Agriculture [74]. Internationally, there are farms that own PV, but blockchain technology has not yet been used in energy management. [75]. The novelty is creating PV parks within farmers' associations (on arid lands, on the surface of irrigation channels, on roofs) [76].
3. Automatic administration of energy management in farmers' associations. Nationally, although smart meters are introduced [77], users do not have control over the energy management, and currently, there are no digital systems for managing energy production and consumption. Internationally, there are companies that produce prepaid smart meters [78] and offer software platforms for their management [79]. They are not intended for use within farmers' associations. In this study, integrating these energy management hardware devices into a dedicated software package for farmers' associations is approached innovatively.
4. Integration of DLT technology for farmers' associations. Nationally, there are software products that implement DLT technologies for data transparency and publication in immutable databases. An example is the SterilTrack product [80]. These products are not addressed to the energy field. Internationally, there are articles on the role of DLT in agriculture, for example, FAOUN published in 2019 a report exemplifying how DLT can make an important contribution to agriculture innovation [81]. It is used in Georgia, USA, for agricultural land registration [18], insurance administration, and supply chain management [82]. The *novelty* is represented integrating the DLT technology for the transparency of the energy trading process in the farmers' associations. It would represent a novelty both at a national and international level, and through this, the project proposal has an innovative character.
5. Tokenization of goods and development of an internal economy. Nationally, there are no specialized products or literature regarding the tokenization of goods and the development of an internal economy within a closed ecosystem. Internationally, there are numerous products and services that facilitate the tokenization of goods and the generation of tokens, such as the ERC20 standard and the ETC721 standard based on the Ethereum blockchain [83], as well as articles in the literature [84]. This practice is regulated by European Directive 2018/843/EU. The novelty is given by researching and implementing the tokenization and developing an internal economy within the farmers' associations.

Developing an IoT software platform with multiple integrations of technologies, such as blockchain, DLT, or APIs (Application Programming Interface) for mobile applications, requires greater attention on the security segment [85,86], this element becoming critical to the smooth operation and to gaining and maintaining the trust of stakeholders [87,88].

The development and realization for the farmers' associations of an innovative prototype application, technologically validated under real conditions, is a technological challenge. In developing the application, ensuring interoperability between these components (such as IoT, blockchain, or Android and iOS applications) requires detailed planning and an overview of goals. In order to avoid integration problems, we will use software libraries globally tested and validated by other entities, applied in similar software solutions. Blockchain technology is at an early stage of adoption, but it is successfully implemented in the financial industry and other industries as well [89].

Jadan Khoun Hossein et al. [90] present the common inverter CMI (cascaded multilevel inverter), which is used in industrial applications. CMIs may be synthesized with non-identical HB cells, as an asymmetric configuration or with identical HB-H bridges, as a symmetric one. Due to its large applicability, this inverter may be used in a wide range of areas—one example is on the PV applications. This topology provides the transformer with less configuration, fault current limiting, and high boosting capability. Using experimental results and simulations, they proved the capabilities of the cascaded multilevel inverter.

Ionescu Mihai Laurențiu et al. [91] propose the structure consumer-producer-distributor developed for the consumer. This method has as a base the genetic algorithm which uses multiple input parameters, such as: Distribution of energy production per unit of time, maximum value of the electricity produced from renewable sources, the time interval in which the unit operates, and the consumption for each unit. This planning method provides a cheaper cost of energy, mostly because green energy has a lower price than classic energy. The method was tested on industrial and individual consumers, and the results presented a 25% cost reduction of the total energy.

Milad Bahrami et al. [92] highlight the solution which uses the PEMFC (polymer electrolyte membrane fuel cell) to obtain electricity from hydrogen energy. Along this device is also included a management system to approach the durability issue and the cost one through the appropriate electrical power distribution between the cell groups. They developed a dynamic model, which was validated using simulations and experimental results. The control method proves its robustness and stability through the used model. This system proves to be effective in three different conditions, and the instability of the cells is solved.

Burin Yodwong et al. [93] present an embedded DC distributed network in a new control law. The approach of a nonlinear differential flatness theory is used to develop a new control algorithm. The performance of the system was verified with a fully digital calculation using MicroLabBox dSPACE platform. Both control structures of the driving cycles; dynamics and steady-state for a 120 V, 40 Ah battery module and a 160 V, 6 F supercapacitor module.

Seung Ju Lee and Yourim Yoon [94] highlight the explosive evolution of the ESSs (energy storage system) among the microgrid and renewable technologies evolution. This system has the capability of controlling the amount of charge/discharge to provide a reduction in the electricity expenses. They propose a method obtained from the combination of dynamic programming and the genetic algorithm. Through the size adjustment of the base units of the dynamic programming, the method's performance is improved.

Maria Simona Raboacă et al. [95] investigate the appropriate solution to fix the range anxiety problem of the EV (electric vehicles) drivers. They highlight the problem caused by space limitations and heavy traffic and propose a novel operational mode for the MCS (mobile charging stations). Their goals are to reach higher efficiency and to optimize the operating costs. The system of temporary location operational mode provides shorter mean queuing time, shorter mean response time, smaller miss ratio, and better efficiency compared with the current moving operational mode.

3.3. Management Platform Dedicated to Farmers Association

The integration of blockchain technology in energy management adds a high degree of transparency and decentralization of data, which leads to the optimization of profits for farmers' associations. The technical solution of the software platform comprises the following components: A backend application, a mobile application, a decentralized distributed ledger technology (DLT) database, and an ERC20 [96] token developed on Ethereum technology and intelligent hardware, starting from the control unit of photovoltaic panels and up to the energy meter of the final consumer. The platform offers farmers associations the possibility to quantify the energy produced by PV in tokens, traded for the energy requirement. The IoT platform will connect to smart sensors for data collection. Minimally, the sensors will be: Photovoltaic panel controller that will count the energy produced and a meter for the energy consumed by water pumps, charging stations, auxiliary equipment, animal farms.

The platform contains three modules:

The backend module will be connected to a distributed ledger technology (DLT) database. This module will consist of the following functionalities:

- administration and record of the associations registered and using the platform;
- administration and record of the users, details, such as PV configuration;
- data stored by each association regarding the energy produced (DLT);
- interface with the Ethereum blockchain for calculating the number of utility tokens held by each user;
- interfacing with the platform's utility token trading market;
- historical data on the amount of energy produced and consumed;
- API interface for the mobile application.

The token (currency) used in smart contracts, developed on the Ethereum blockchain network using the ERC20 standard, and the Solidity programming language is used within the network.

The trading currency has a total fixed offer, without the possibility of generating multiple units in the future. The users (farmers' associations) will receive this token through the application when they generate energy from the photovoltaic panels. The token can only be traded within the platform (utility token), the price being determined by supply and demand. Through the application, blockchain technology allows the token to be changed into an amount of energy (which can be pre-configured as fixed or dynamic, depending on the demand and supply). Token administration will be done only through the mobile application.

The mobile application compatible with IOS and Android has the following features (Figures 4 and 5):

- Control over the program for energy consumption by the consumer, in order not to centralize the network;
- Monitoring of produced energy (real-time and historical);
- Monitoring of energy consumption (real-time and historical);
- "Wallet" for the token with trading possibility [97,98].

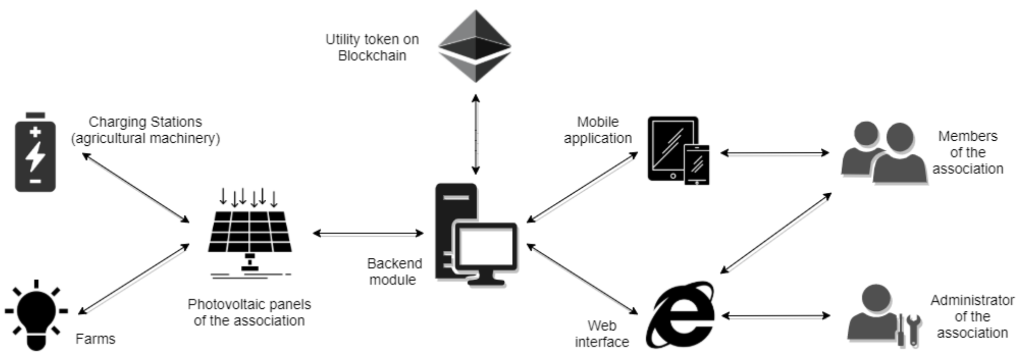

Figure 4. Digital Platform.

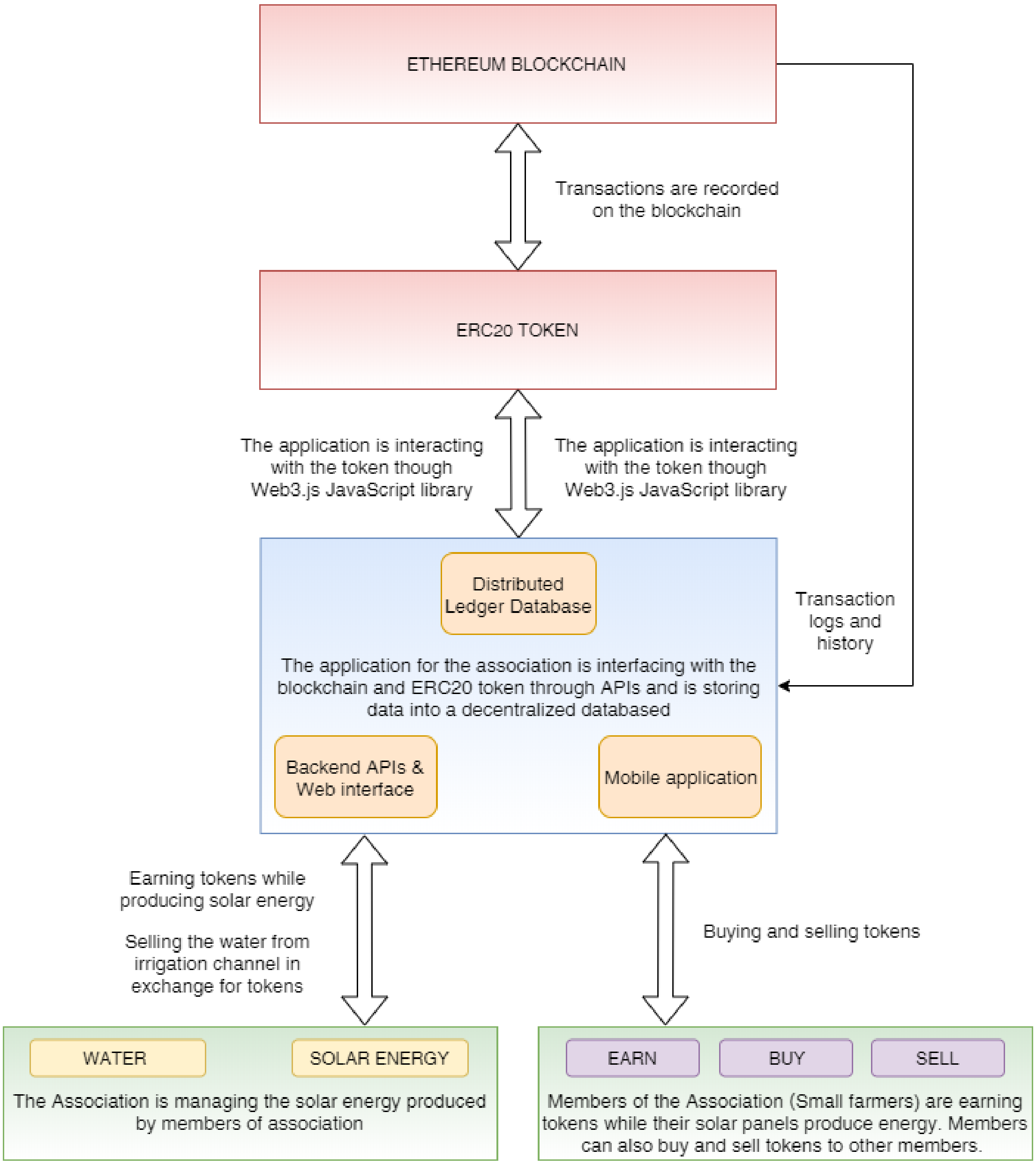

Figure 5. Blockchain-based smart contract system.

4. Results and Discussion

A. Working principle

The operating principle is simple to use by a wide range of users.

Step 1: Each member of the association must create an account on the platform by filling in the registration form

Step 2: Once the registration is finished, the new user must complete his profile within the platform. The platform will be compliant with the current legislation concerning personal data protection and privacy and the General Data Protection Regulation (GDPR), to assure user privacy. The information stored in the Distributed Ledger Database will contain only pseudo-anonymized data.

Step 3: Each user must register and connect their photovoltaic system to the platform. A setup guide will be available, in which the user will be guided to connect their photovoltaic system to the platform. Once the setup is done, the data communication between the photovoltaic system and the platform will be established.

After the enrolment of users into the platform, the next steps are related to accessing the data and enabling decentralized transactions using blockchain and smart contracts. Creating an internal economy based on a decentralized utility token within a group of farmers can reduce costs related to energy distributors.

B. Accessing the data

Within the platform, the user will have access to a pre-initialized dashboard, that will include details on:

- energy produced
- energy consumed for their own use
- energy distributed into the association grid to association members or others
- conversion rate of energy produced in related interest to tokens
- token balance
- token trading—smart contracts management [99]

Each member will have access to a dashboard with data, such as the daily energy consumed or produced, tokens balance, conversion rate, etc.

C. Implementing the application and samples from the results obtained

The developed application includes a utility token based on the Ethereum blockchain and a REST Application Programming Interface for managing profiles, data, and trading.

(a) User Interface

The platform interface was built using the Truffle framework and Web3.js library for interfacing with Ropsten Ethereum testnet.

The figures below sample code snippets representing the token creation using Solidity (Figure 6) and the deployment to the testnet blockchain (Figure 7). The implementation makes use of the Open Zeppelin, an open-source contracts library.

```
if __name__ == '__main__':
    """
    Create a ledger and wait for it to be active.
    """
    try:
        create_ledger(Constants.LEDGER_NAME)
        wait_for_active(Constants.LEDGER_NAME)
    except Exception as e:
        logger.exception('Unable to create the ledger!')
        raise e
```

Figure 6. Creating the ledger using AWS (Amazon Web Services), SDK (Software Development Kit) for Python.

```
{
 TenantId: "FLzkPYLdki3Vm6Sw",
 EnergyProduced: "11",
 Timestamp: "1599657128"
}
```

Figure 7. Querying the production of a specific tenant in the ledger.

The user interface (UI) was developed using specific smart contracts development frameworks (Truffle) for the front-end and for the connection with the Ethereum blockchain testnet (Web3.js configured with the Robsten network) (Figures 8 and 9).


```
{
 blockAddress: {
  strandId: "Lo2LyjTbSPg63RLuLcpAKt",
  sequenceNo: 15
 },
 hash: {{ddnhlS2YmqS8h/s71mgcQnAlB1DW6omYz6OW0cxuk9k=}},
 data: {
  TenantId: "FLzkPYLdki3Vm6Sw",
  TokenBalance: "56",
  Timestamp: "1599657029",
  Transaction: "G621"
 },
 metadata: {
  id: "9WqqMRzYY23IKUhen9S37n",
  version: 0,
  txTime: 2020-09-09T13:15:35.951Z,
  txId: "4NTN3LvCl720jroQNxnfE4"
 }
}
```


Figure 8. The output of "TokenBalance" table history.


```
{"digest":"Bo95NmIj190S0r9p2y7gvTqSNyOnXiLHawXNp+mcF9Y=",

"digestTipAddress":"{strandId:
\"Lo2LyjTbSPg63RLuLcpAKt\",sequenceNo:20}",

"ledger":"SmartFarmLedger",

"date":"2020-09-09T13:22:08.549Z"}
```


Figure 9. The SHA-256 hash value, which is used to verifying the latest committed block and validity of the journal.

(b) Deploy the contract to Ropsten

The token deployment to the testnet blockchain will be made with the Truffe framework.

1. Build the smart contract with the following console command:

truffle build

2. Deploy the contract:

(c) Truffle deploy ± network Ropsten

Once the contract is deployed, the platform can make use of the token, enabling transfers between members, facilitating token exchanges for energy or water. Remix Ethereum IDE will be used for initial functional and security testing.

(d) Setting up the DLT ledger using the AWS (Amazon Web Services), QLDB (Amazon Quantum Ledger Database) service

Using the AWS (Amazon Web Services), SDK (Software Development Kit) for Python, we managed to connect, create, insert data, and verify an immutable ledger.

Querying the data can be done using customer APIs built on top of the AWS SDK, or can be done using Streams or directly thought the AWS console.

Querying the revision history of the ledger can be achieved using the PartiQL extension and the history function. For example: SELECT * FROM history (TokenBalance), resulting in an output that includes metadata attributes that provide details on when each item was modified, and by which transaction. The document is uniquely identified by a UUID that is represented in a Base62-encoded string.

The verification of the ledger can be achieved by requesting a digest and verifying the data using the GetDigest, GetBlock, and GetRevision functions from the QLDB API.

D. Financial forecasts

The paper presents the results of a pilot project, which demonstrates that the design concept and business proposal are feasible based on financial forecasts presented in this section. The purpose of forecasting and analyzing performance indicators is to demonstrate that the project is financially sustainable.

(a) Description of working hypotheses

A net discount rate of I = 4% was considered, according to the "Guide to Cost-Benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014–2020" and a reference period of 10 years, taking into account the field of activity and the specificity of the product and the target market.

Until year 2, the activities are related to the research stage and represent the implementation situation of this pilot project. Year 3 (2021) is related to the development of the commercial product starting from the results of the research carried out in the previous two years. Starting with year 4 until year 8, the product is exploited to obtain income.

The methodology used to calculate the financial indicators is that of the analysis of the discounted cash flow, which considers at the end of the reference period, the residual value of the product. To determine this, a value of growth in perpetuity of 1% was taken into account.

(b) Forecasting sales prices

Revenues from the sale of services in the form of subscription and were estimated, taking into account an annual price of 600 EUR/year/farm in the first year. This price is the equivalent of approximately 50 EUR/month, an attractive price in relation to the benefits offered at the farm level. It is envisaged a decrease by 10% per year in the price in the following years, until it drops to approximately 390 EUR/year, after which it remains constant according to Table 2.

Table 2. Forecasting sales prices and volume.

	Research		Production	Exploitation						
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Customers number	0	0	0	200	300	435	566	691	767	805
Sales	0	0	0	116,000	156,600	204,363	239,305	262,995	291,920	306,383
Subscription price	-	-	-	580	522	470	423	381	381	381

(c) Forecasting sales volume

Given the size of the market, we anticipate a number of 200 farms that will become customers of the platform in the first year of operation (Year 4). The number of customers will increase following a typical forecast curve, with a faster pace at the beginning of the interval and which will experience a flattening towards the end of the reference period.

(d) Estimation of cost elements

Cash outflows were calculated based on the averages recorded at the organization level per employee for categories K2–5, K7, K8, and K10, considering the average number of employees forecast for each period. Expenditures for K6 and K9 were determined based on experience gained in carrying out other projects. K1 expenses are lower than the company average for sales of the developed product, being strictly related to services. The cost categories and projected values are presented in Table 3.

(e) Forecast financial statements for the version with the implemented project, respectively the current version (without the implemented project)

Based on the working assumptions, the profit and loss account for the current version (without the implemented project) is presented in Table 4.

Taking into account the cost elements and revenues in the case of project implementation, the profit and loss account is presented in Table 5.

Table 3. Estimation of cost elements.

Research			Production			Exploitation				
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
K1. Raw materials and materials	Note: Expenses according to the project budget, covered by non-reimbursable financing and own contributions.		−120,000	−1260	−1323	−1389	−1459	−1532	−1608	−1689
K2. Staff costs (including contributions)			−129,514	−64,757	−97,135	−129,514	−161,892	−194,270	−210,460	−226,649
K3. Rents, operating leasing royalties			−3309	−1654	−2482	−3309	−4136	−4963	−5377	−5790
K4. Utilities (fuel, energy, water, etc.)			−1614	−807	−1211	−1614	−2018	−2422	−2623	−2825
K5. Transport			−190	−95	−143	−190	−238	−286	−309	−333
K6. Advertisement			−1500	−25,000	−26,250	−27,562	−28,941	−30,388	−31,907	−33,502
K7. Trips			−3211	−1606	−2408	−3211	−4014	−4817	−5218	−5620
K8. Maintenance, upkeep, repairs, etc.			−5846	−2923	−4388	−5846	−7308	−8770	−9500	−10,231
K9. Training			−2240	−1120	−1680	−2240	−2800	−3360	−3640	−3920
K10. Taxes on buildings, land, cars, etc.			−1998	−999	−1499	−1998	−2498	−2998	−3247	−3497
Total cash outflows			−150,623	−100,222	−138,515	−176,875	−215,303	−253,804	−273,890	−294,057

Total cash outflows.

Table 4. Profit and loss account for the current version.

Reference Years		Indicator name	Research		Production	Exploitation						
2017	**2018**		**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
2927,593	4206,667	**Total income**	5587,811	6399,399	6603,415	6933,586	7280,265	7498,673	7723,634	7955,343	8194,003	8439,823
187,387	243,204	**Cost of the sold goods**	291,845	321,033	330,660	340,580	350,797	357,813	364,970	372,269	379,714	387,309
2740,206	3963,463	**Gross edge**	5295,966	6078,370	6272,755	6593,006	6929,468	7140,860	7358,664	7583,074	7814,289	8052,514
2000,452	2931,366	**Expenses related to sales, administrative**	3898,717	4561,498	4835,188	5125,300	5432,818	5704,459	5989,681	6289,166	6603,624	6933,805
228,341	315,984	**Other operating expenses**	539,402	602,134	521,204	552,477	585,625	614,907	645,652	677,935	711,831	747,423
511,414	716,113	**Operational profit**	857,847	914,737	916,362	915,230	911,025	821,495	723,331	615,974	498,833	371,287
36,113	34,424	**Financial expenses**	36,145	37,953	39,091	40,264	41,472	42,301	43,147	44,010	44,891	45,788
28,608	15,501	**Financial income**	15,966	16,445	16,774	17,109	17,451	17,801	18,157	18,520	18,890	19,268
503,909	697,190	**Profit before tax**	837,668	893,229	894,045	892,075	887,005	796,994	698,340	590,483	472,833	344,766
72,455	96,607	**Taxes**	134,027	142,917	143,053	142,732	141,921	127,519	111,734	94,477	75,653	55,163
431,455	600,583	**Net profit financial year**	703,641	750,312	750,998	749,343	745,084	669,475	586,605	496,006	397,180	289,603
0	0	**Net loss financial year**	0	0	0	0	0	0	0	0	0	0

Table 5. Cost elements and revenues in the case of project implementation, the profit and loss account.

Reference Years		Indicator Name	Research		Production			Exploitation			
2017	**2018**		**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
2927,593	4206,667	Total income	55,878,109	6399,399	6754,159	7049,586	7436,865	7703,036	7942,938	8218,337	8485,923	8746,206
187,387	243,204	Cost of the sold goods	291,845	321,029	330,660	340,580	350,797	357,813	364,970	372,269	379,714	387,309
2740,206	3963,463	Gross edge	5295,966	6078,370	6423,378	6709,006	7086,068	7345,223	7597,969	7846,068	8106,209	8358,897
2000,452	2931,366	Expenses related to sales, administrative	3898,717	4561,498	4835,188	5225,521	5571,333	5881,333	6204,985	6542,970	6877,514	7227,861
228,341	315,984	Other operating expenses	539,402	602,134	671,828	552,477	585,625	614,907	645,652	677,935	711,831	747,423
511,414	716,113	Operational profit	857,847	914,737	916,362	931,008	929,110	848,983	747,332	625,164	516,863	383,613
36,113	34,424	Financial expenses	36,145	37,953	39,091	40,264	41,472	42,301	43,147	44,010	44,891	45,788
28,608	15,501	Financial income	15,966	16,445	16,774	17,109	17,451	17,801	18,157	18,520	18,890	19,268
503,909	697,190	Profit before tax	837,668	893,229	894,045	907,853	905,089	824,482	722,341	599,673	490,863	357,092
72,455	96,607	Taxes	134,027	142,917	143,047	145,257	144,814	131,917	115,575	95,948	78,538	57,135
431,455	600,583	Net profit financial year	703,641	750,312	750,998	762,597	760,275	692,565	606,767	503,726	412,325	299,958
0	0	Net loss financial year	0	0	0	0	0	0	0	0	0	0

A comparison of the values obtained for revenues, operating profit, and net profit shows higher values in the case of project implementation.

(f) Analysis of financial profitability indicators

The calculation of the financial net present value (FNPV) was done with Equation (1):

$$FNPV(C) = \sum_{t=0}^{n} a_i S_i = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \ldots + \frac{S_n}{(1+i)^n} \tag{1}$$

where St is the net flow in year t, and i is the net discount rate. The last cash flow considered also includes residual value.

The calculation of the residual value of the investment was made with Equation (1):

$$VR = \frac{CF_{n+1}}{i-g} \tag{2}$$

where g represents the perpetual increase of the net flow at the end of the reference period, and for it, the value of 1% was considered.

Corresponding to the data presented in the Tables, it is obtained:

VR = 348,593.09

FNPV = −172,035.83 < 0

The internal rate of return (IRR), being the value of the net discount rate for which the net present value becomes zero, results as:

RIR = 2.498% < 4%

The negative value of FNPV and a value of the internal rate of return lower than the value of the net discount rate show that the project requires non-reimbursable financing in the first two years.

(g) Profitability analysis

The profitability and profitability of the own contribution invested in the project considering only the company's contribution to the project will be:

FNPV = 93,312.24

RIR = 8084% > 4%

5. Conclusions

The proposed energy management platform is a solution that responds to the actual needs of the agricultural sector in terms of climate change, renewable energy, and production capacities.

Blockchain technologies bring innovation in multiple industries, such as agriculture, automotive, smart city, energy, tourism, health, water, public administration, etc. In every industry, we can identify defects, blanks, errors, problems, etc., elements that have a considerable impact, but which can be solved with the help of blockchain implementation. As previewed, blockchain implementation brings value and development at a local and national level in all the sectors. This has immeasurable benefits on peoples' lives, having a positive impact on their daily work and quality of life, from a financial and health perspective. The transparency, security, privacy that blockchain provides meet human needs and provide a cleaner and more welcoming future for our children.

By using solar power in the production processes (light, heat, energy for agricultural electric equipment such water pumps, agricultural electric vehicles, etc.) farmers can increase their energy independence and cut costs—especially high costs in getting energy to their production sites. Furthermore, they reduce the carbon footprint, while growing their crops by using non-polluting equipment and vehicles. They can also have an additional source of income from trading the surplus energy and even resources, into a transparent market.

The proposed innovative solution offers farmers and farmers' associations an easy-to-use tool that helps them become energy independent by developing an internal economy within the association based on a smart private contract system without intermediaries, which is monetized by utility tokens. The main findings of this study can be summarized as follows:

- It has been shown that the solution proposed in agriculture brings several benefits related to financial improvements and economic growth of agricultural farms by creating photovoltaic parks on arid land, on the surface of irrigation canals, etc., and last but not least, to reducing pollution.
- The integration of smart blockchain contracts for energy management in farmers' associations offers increased efficiency and easier and safer access to agricultural services.
- The security, traceability, and certification of financial processes are improved by integrating DLT technology for farmers' associations and publishing data in immutable databases, helping governance to enforce the legal, regulatory framework and stop food fraud.
- The smart marketing developed within the application allows farmers to make agriculture more efficient and to recycle more.
- The proposed application ensures easier access to agricultural services and insurance, improves the working environment, and facilitates finding employment by implementing tokenization and developing an internal economy within farmers' associations in accordance with European Directive 2018/843/EU

This internal economy has the capacity to stimulate farmers to adopt future technologies that can respond to different problems in terms of capitalizing on local resources, self-producing, and self-management of those. The future of this technology is open, and therefore, subject to improvements, and this paper is intended to be a basis for further research in this field.

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