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# The Use of Blockchain Technology in Public Sector Entities Management: An Example of Security and Energy Efficiency in Cloud Computing Data Processing

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**Abstract:** Blockchain technology is currently one of the trends considered to have a tremendous future ahead. It ensures data security, data sharing protection and automation development—elements that are of colossal importance in the era of cloud solutions, big data and Internet of Things (IoT) reality. Additionally, blockchain technology allows one to create new programmable ecosystems on an unprecedented scale. The implementation of blockchain technology leads not only to improving the flow of documents and data storage, as is the case with the creation of shared service centers (SSCs), but—as this paper shows—allows one to reduce the carbon footprint when servicing SSCs at a considerably higher organizational level at the same time. The example of an SSC in Elbląg, Poland, proves that cloud solutions enabling electronic documents flow and data storage combined with blockchain technology are tools essential for further SSCs development. Furthermore, such tools allow us not only to obtain economic effects (i.e., cost reduction), but also to achieve positive ecological effects (i.e., carbon footprint reduction).

**Keywords:** energy efficiency; cloud computing; blockchain technology; public administration management; data security; Internet of Things (IoT)

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**Citation:** Karaszewski, R.; Modrzyński, P.; Modrzyńska, J. The Use of Blockchain Technology in Public Sector Entities Management: An Example of Security and Energy Efficiency in Cloud Computing Data Processing. *Energies* **2021**, *14*, 1873. https://doi.org/10.3390/en14071873

Academic Editor: Joao Ferreira

Received: 25 January 2021
Accepted: 22 March 2021
Published: 29 March 2021



## 1. Introduction

Energy efficiency, reduction of energy consumption, reduction of $CO_2$ emissions and reduction of carbon footprint are concepts that have become permanent in international and national strategic documents, legal regulations, standards of implemented technological and technical solutions, scientific priorities and implemented projects in business and the public sector. Issues regarding energy efficiency have gained significant importance in recent decades, when accelerating climate change left no illusions as to the need to take immediate actions to slow it down. The European Union (EU) in particular shows a great interest in the problem. The EU's concern about the problem manifests in many regulations among which the following should be mentioned: the communication of the Commission of the European Communities [1], which emphasizes the need to reduce energy consumption in the Member States by 20% by 2020 (compared to 1990). Moreover, the communication directly refers to the European strategy for sustainable, competitive and safe energy [2]. Despite lofty assumptions, the goals of reducing energy consumption by the EU members have not been achieved; therefore, in 2011, the Commission had to revise them [3]. The revised assumptions were aimed at catching up and achieving the EU target of reducing energy consumption still by 20% compared to 1990 (but this time in the long run—by 2050, at the latest), and supporting the implementation of the low-emission economy based on efficient use of resources. Recent years have also brought numerous directives [4,5] or communications of the European Commission [4,6–9] regarding energy efficiency. With the additional help of numerous financial resources and programs aimed at minimizing the negative impact of human activity on the environment, including ever faster climate change, it is not surprising that the expert and scientific communities began to look for new methods that would prove to be more effective than before.

In this context, proposals regarding the use of blockchain technology began to appear more and more often. Its significance in the process of increasing the efficiency of pro-ecological investments aimed at reducing energy consumption and/or $CO_2$ emissions has been recently widely discussed [10–14]. Although blockchain technology is primarily seen in the context of securing data access (e.g., in trading cryptocurrency, e.g., Bitcoin or Ethereum), it is necessary to start perceiving it in a much wider context. According to Davidson et al. [15], blockchain technology should not be seen as part of the ICT revolution only, but instead more as an evolution (or even revolution) in institutions, organization and governance. Therefore, it should be noted that blockchain is currently used on an increasing scale also in the context of broadly understood ecological activities aimed at ensuring sustainable development and environmental protection. In addition to using technology to increase the efficiency of energy consumption and reduce its amount, blockchain technology is already used for a decentralized immutable public water transactions record and helps in discovering complex patterns in big data on shifting water distribution by consistently executing small-scale scientific processes. Blockchain data protocols already yield advantages in efficient water abundance and ensure multi-sale water resource management under climate change conditions [16]. The technology has also found application in the area of marine data storage, management sharing and application [17].

MIT experts [18] (p. 3) pay attention to the fact that existing tools for solving global problems are outdated, inadequate and inefficient. "We now face the challenges of global warming, uncertain energy, water, and food supplies, and a rising population that will add 350 million people to the urban population by 2025 in China alone. The new challenge is how to build an infrastructure that enables cities to be energy efficient, have secure food and water supplies, be protected from pandemics, and have better governance. Big data can enable us to achieve such goals. Rather than static systems separated by function—water, food, waste, transport, education, energy—we can instead regard the systems as dynamic, data-driven networks. Instead of focusing only on access and distribution, we need networked and self-regulating systems, driven by the needs and preferences of citizens—a 'nervous system' that maintains the stability of government, energy, and public health systems around the globe. A control framework should be established which enables data to be captured about different situations, those observations to be combined with models of demand and dynamic reaction, and the resulting predictions to be used to tune the nervous system to match those needs and preferences. Blockchain's highly resilient architecture and distributed nature make it an interesting platform to deliver this nervous system for society".

The benefits of using blockchain technology in regards to environmental protection by increasing energy efficiency, are in the limelight of this paper. The problem of energy efficiency has already been subject of many studies. Among others, M. Schletz et al. [13] analyzed three examples of implementations: (1) peer-to-peer energy trading, (2) White Certificate Scheme and (3) Energy Service Companies. Their research indicates that the functionalities and possibilities of using blockchain technology depend on a specific implementation and the adopted management model, and the versatility of the technology allows it to be used in very diverse areas. Among these, energy efficiency can be noted and developed.

According to Shrier et al. [18], the contemporary world is rapidly undergoing a fundamental change—change that is primarily driven by data and its effective use. Undoubtedly, cloud computing solutions and blockchain technology are unique and currently they have no competitor or equivalent as far as storage and securing online authentication of data (and especially, big data) are concerned. The possibility of universal use of blockchain technology can have a wide range of applications, including the broadly understood areas of eco-efficiency.

The article consist of six parts. In the introduction, the authors review the contemporary literature on energy efficiency and blockchain technology as well as key documents regarding these issues. The second part is devoted to blockchain technology and the possibilities of its use, among others, in SSCs functioning. The third section describes the methodology of preparing the article. The fourth part relates to SSCs existing in Poland and the possibility of using blockchain technology in their operations. An example of such use is described in part five. In the last section, the authors presented the conclusions from the conducted research.

## 2. Results and Discussion

### *2.1. Blockchain Technology—Overview*

Before we move on to the possibility of using blockchain in the pursuit of energy efficiency, the technology itself should be described a bit more closely. In all the above-mentioned examples, blockchain technology that assumes the transmission of data blocks is used to store and transmit information about transactions concluded on the Internet [19]. According to Yang et al., blockchain technology can be characterized by four main features: decentralization, consensus mechanism, traceability and high trust [20]. Blockchain owes its popularity and more and more widespread use primarily to the belief that its time-stamped blocks are considered impossible to corrupt or change. However, the list of the advantages of blockchain technology is undoubtedly much longer. The use of blockchain for the organization of processes implemented as part of investment projects or the provision of services, as shown by the case study described below, allows one to achieve additional economic and quality effects—including energy efficiency. According to experts [21], more and more modern energy companies use blockchain technology due to its ability to improve existing processes and create new, additional functions, such as: trade of goods, P2P energy trading, elimination of retail intermediaries or data management. The main goal of these activities is to create a fully automated energy market where it would be possible not only to reduce the imbalance costs of the current power systems, but also to increase the overall efficiency of the entire system. It has to be emphasized that the energy sector is not the only area where blockchain technology is currently used, or where it could be used in the near future. Business services, settlement of financial assets, conducting financial transactions, including using derivatives, are just some of the numerous areas that allow the use of a wide range of possibilities offered by blockchain technology [22–27]. The Figure 1 chart below shows the scale of opportunities accessible thanks to blockchain technology [28].

Blockchain is, simply put, a timestamp of a series of invariant data records managed by a cluster of computers that are not owned by any entity involved in the transaction—that is—in this case—a given SSC and a serviced entity. Each of these data blocks is secured and linked to another using cryptographic rules (e.g., chains). It means that in order to access the data, read it, modify it or update it, you need a valid public key that refers to a given location, database name and private key in the form of a personalized file assigned to each user [29] (Figure 2).

So far, both scientists and practitioners have emphasized above all that with regards to financial institutions, blockchain technology provides better data infrastructures, and a better quality of delivered services that can be delivered more comprehensively and at considerably lower costs. Blockchain technology also enhances credibility assurance and security while providing a network authentication mechanism [30]. Moreover, MIT experts emphasize [18] that blockchain holds the promise of becoming the "New Deal on Data" and has endless benefit for data aggregation. They also claim that a successful data-driven society must be guaranteed that its data will not be abused. All the above mentioned elements are of extreme importance; however, there is an element that experts often forget or do not take into account at all. This element is the extremely advantageous side benefits associated, for example, with the possibility of reducing time needed to deliver and exchange documents, paper and office supplies consumption, and transport of documents, all of which in turn result in a significant reduction of carbon footprint. Therefore, one of the latest big data technological achievements, and as such, a change in how blockchain technology can be perceived, should be considered not only in the context of big data management and storage security, but also in regards to the environmental benefits it can add. The development of cloud platforms, operating globally and offering various services such as virtual hardware, software or access to services, gives theoretically unlimited possibilities and is currently the leading direction of technology development. The development of cloud services and the popularization of application-based services requires the use of new virtual network architectures that ensure network sharing as well as support for large data storage provided with Internet of Things (IoT) devices. Such examples are two complementary architectures: software defined networks (SDN) and network function virtualization (NFV), which additionally contribute to obtaining significant energy savings compared to existing 4G hardware technologies [31].


**Figure 1.** Mindmap abstraction of different types of blockchain applications. Source: Casino, F., Dasaklis, T.K., Patsakis, C., *A systematic literature review of blockchain-based applications: Current status, classification and open issues*, Telematics and Informatics 36, 2019, p. 62 [28].

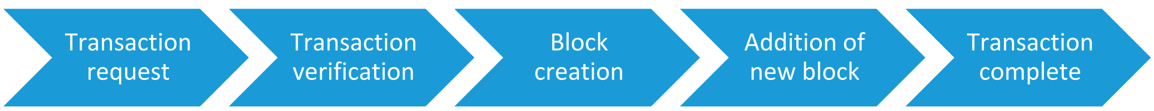


**Figure 2.** Blockchain technology: process. Source: Lakshmi and Sricharan, 2019, p. 1784 [29].

In the area of energy efficiency research, the public (with special regard to local government) sector is a natural entity present on the market, acting both as a legislator and administrator of public funds supporting projects reducing media consumption or an active beneficiary of these funds. Global trends taking place in the last decades in the public sector indicate the growing impact of business solutions and standards in reforming the operational efficiency, functioning and organization of the public sector entities. The initiation of public administration reforms in the 1980s, referred to in the literature as New Public Management, focused the attention of decision-makers on the implementation of public sector organization and management models based on performance measures and being goal-oriented [32–37]. An excellent example of implementing business solutions aimed at reducing costs, increasing the level of management efficiency and, consequently, the effectiveness of implemented processes is the creation of Shared Service Centers (SSCs) supporting public sector units [38–44]. SSCs operating in both the private and public sectors focus on the provision of shared services, including primarily accounting, payroll, tax, IT and legal services [44–48]. The range of shared services available to deliver is wide, which is confirmed by the analyses of individual implementations. In addition to standard services, shared services may also include energy audit services. The examples of Wodonga City and the Rural City of Wangaratta in Australia, where an SSC providing shared services of energy audits was established, are an excellent cases of combining energy efficiency projects with effective organizational solutions [49]. Based on the literature review, there is a growing tendency to combine energy efficiency projects and optimize their management systems in order to maximize economic and environmental benefits. The increasingly popular Shared Service Centres using, inter alia, blockchain technology while securing performed processes, can be an excellent technological support increasing the effectiveness of projects and services provided.

### 2.2. Methodology

The main purpose of this article is to present the possibilities of further development of SSCs thanks to the use of cloud solutions and blockchain technology in the provision of shared services at the local government SSCs in Poland.

The main research problem that the authors of this article focused on was the role and possibilities of using blockchain technology in the further development of SSCs, taking into account not only the potential economic profits, but also the energy and environmental benefits of this solution.

This article was prepared on the basis of a case study and is an example of an exploratory approach based on the following research questions: (1) Are further stages of development of SSCs possible, or have they reached their maximum development potential? (2) Is it possible to achieve noticeable economic effects and/or better energy efficiency in SSCs, and if so, what tools can contribute to achieving it? (3) Why are or could SSCs be interested in improving energy efficiency?

The research methods adopted while preparing the paper include the law and institutional analysis: an examination of the content of legal acts and other documents in order to select and interpret the documents suitable for the research aim. In addition, the verification of the research questions was carried out on the basis of the analysis of the results of the implementation of the local government Shared Services Centre in the Polish city of Elbląg. The Elbląg SSC provides shared services that use blockchain technology for 61 organizational units of the municipality of Elbląg. The combination of the legal basis exploration and their practical application allowed for a thorough analysis of the possibilities offered by the use of blockchain technology. Examination of the SSC in Elbląg will allow one to assess the usefulness of blockchain technology in regards to the management of public sector entities, increasing the effectiveness of their operation and achieving positive economic and environmental results related to reduction of $CO_2$ emissions. Additionally, the analysis will make it possible to use the obtained conclusions and extrapolate them to other SSCs operating in the public administration sector in Poland.

Legislative changes that took place in Poland in 2015 allowed local governments to provide specific services as part of shared services by creating an SSC [44]. From that moment on, these units have been created on a large scale to improve the processes of organization and functioning of local government administration. The study of the local government shared services market regarding the largest Polish cities (members of the Union of Polish Metropolises) shows that 80% of them have already established an SSC [50]. The search for the possibility of further increasing the economic efficiency of the SSCs within their scale of operation becomes of great importance. More and more SSCs are beginning to perceive blockchain technology as one of the key tools (if not the most important) allowing them not only to improve the functioning of SSCs, but also to improve significantly their efficiency. Moreover, the use of blockchain technology leads to additional benefits and increased ecological and energy efficiency, which directly fits into the global trends of corporate social responsibility, also, and perhaps above all, in the public sector.

### *2.3. Shared Services Centres in Public Sector in Poland*

The public sector, with particular emphasis on the local government sector in Poland, similar to other countries [51], has long been looking for solutions to increase operational efficiency and reduce costs. The case of the public sector proves that the implementation of organizational changes has another, very important advantage—the security of the processes carried out and the expenditure of public funds. The conducted research, both in cooperation with the Union of Polish Metropolises (UMP), which brings together the largest cities in Poland, and the Union of Polish Poviats (ZPP), which brings together almost all poviats in Poland, have shown that it is precisely the goals of ensuring the safety and control (i.e., management effectiveness, harmonization, risk reduction, innovation tools) that were crucial for making decisions on introducing organizational changes and creating SSCs in local governments [52] (Figure 3).

The process of creating SSCs in Poland can be divided into three stages, depending on the level of advancement of organizational and technological solutions used in the provision of shared services (Figure 4).

The process of creating shared service centers by local government units in Poland usually is carried out in stages, or a specific organizational model is implemented. The first stage usually includes activities regarding standardization of the implemented processes. Its effects have a direct impact on the increase in the level of efficiency of the operations of the serviced units and the safety of the processes carried out [53] (Figure 5).

It is worth emphasizing that the process of creating local government shared service centers is similar to the development phases of units operating in business. The PricewaterhouseCoopers report presents the process of evolution of SSC business models, in which, inter alia, eight key criteria of the evolution of these units were characterized. According to the report, the final effect of the process is the creation of the so-called 2nd generation SSCs. The key criteria enabling the creation of the 2nd generation SSC include the use of IT systems and technologies enabling the automation and standardization of processes and the integration of systems based on electronic document flow [53].

When researching energy efficiency or environmental performance in general, particularly interesting models are those in which cloud solutions appear, on which the functioning of SSCs and the provision of shared service are based. The use of cloud solutions by the public/local government sector is the first step towards implementing solutions increasing the effectiveness of implemented organizational features, i.e., in the area of management [43,54–56] and solutions for energy efficiency related to the reduction of material and energy consumption during the implementation of shared service processes [57]. This approach reflects the implementation of ecological and energy-efficient solutions in all possible areas of performed tasks and thus fits in with the assumptions (tasks) of corporate social responsibility of the public sector [58]. In Poland, after 5 years of implementing particular legal solutions [59], the first stage of creating an SSC is already widely known to local governments. The experience to date shows that shared services usually focus on the area of accounting and payroll services and are addressed to units that perform fairly uniform statutory tasks—most often these are educational units. The process of creating the SSC is also associated, if it has not been done before, with the implementation of uniform software supporting the scope of the shared services provided. The results of the research on the functioning of the local government shared services market indicate [60] that the key element of an effectively provided shared service is the implementation of IT technologies based on cloud solutions, enabling the creation of common databases and the implementation of shared services for numerous units. In many local governments, organizational units previously used software that had their own local database. The process of transition to shared services forced the merging of these single databases containing key financial and accounting information as well as human resources (HR) and payroll information (second stage—Figure 4). Many SSCs currently operating in local government structures stopped at this stage. However, introduction of modern cloud technologies allowing safe data sharing and securing of data copies in virtual disk space opened up completely new possibilities for SSCs. This way, SSCs were able to overcome one of the main organizational obstacles (i.e., the physical delivery and the need to work on paper documents), which was related to the necessity of ensuring information security and had a huge impact on the efficiency of the SSCs and the shared service they deliver. Transport of documents from serviced units to the SSC and from the SSC to the serviced units (e.g., documents signed by the head of the unit and generated from the payroll system) is a labor-intensive and cost-consuming activity, and additionally, it is potentially threatened with leakage of sensitive data (e.g., gaining access to documents by unauthorized persons, loss of documents, etc.). The number of documents and the high frequency of their delivery are a significant organizational challenge for both the SSC and the units served. Delivering shared services on a large scale and for many units with the use of anachronistic tools, and as such, the use of paper documents, should be perceived as standing in opposition to the basic goals underlying the implementation of SSCs, namely: increasing the efficiency and safety of the processes.

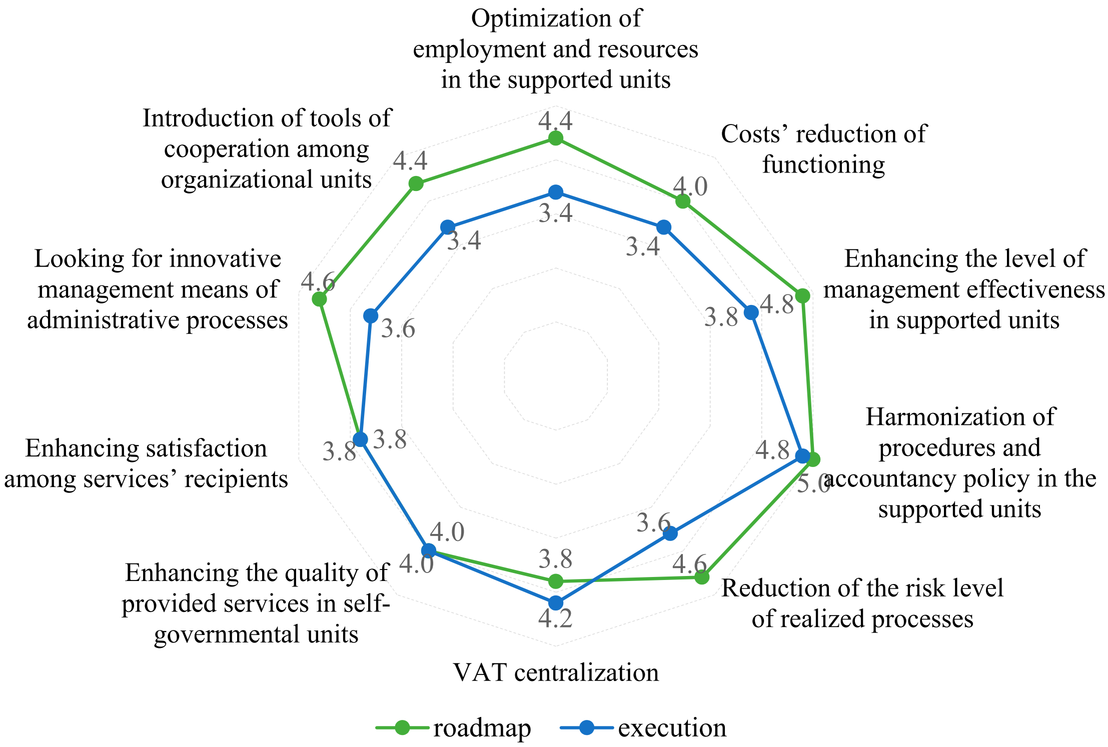


**Figure 3.** Main objectives in the process of establishing shared service centers (SSCs) (supported unit treasurer evaluation—a roadmap and its execution). Source: Modrzyński, P., Gawłowski, R., Modrzyńska, J. (2019). *Local Shared Service Centres. Analysis of functioning and evaluation of provided service effectiveness*, https://www.portalsamorzadowy.pl/pliki-download/134596.html, access dated on 10 March 2020, p. 14 [50].

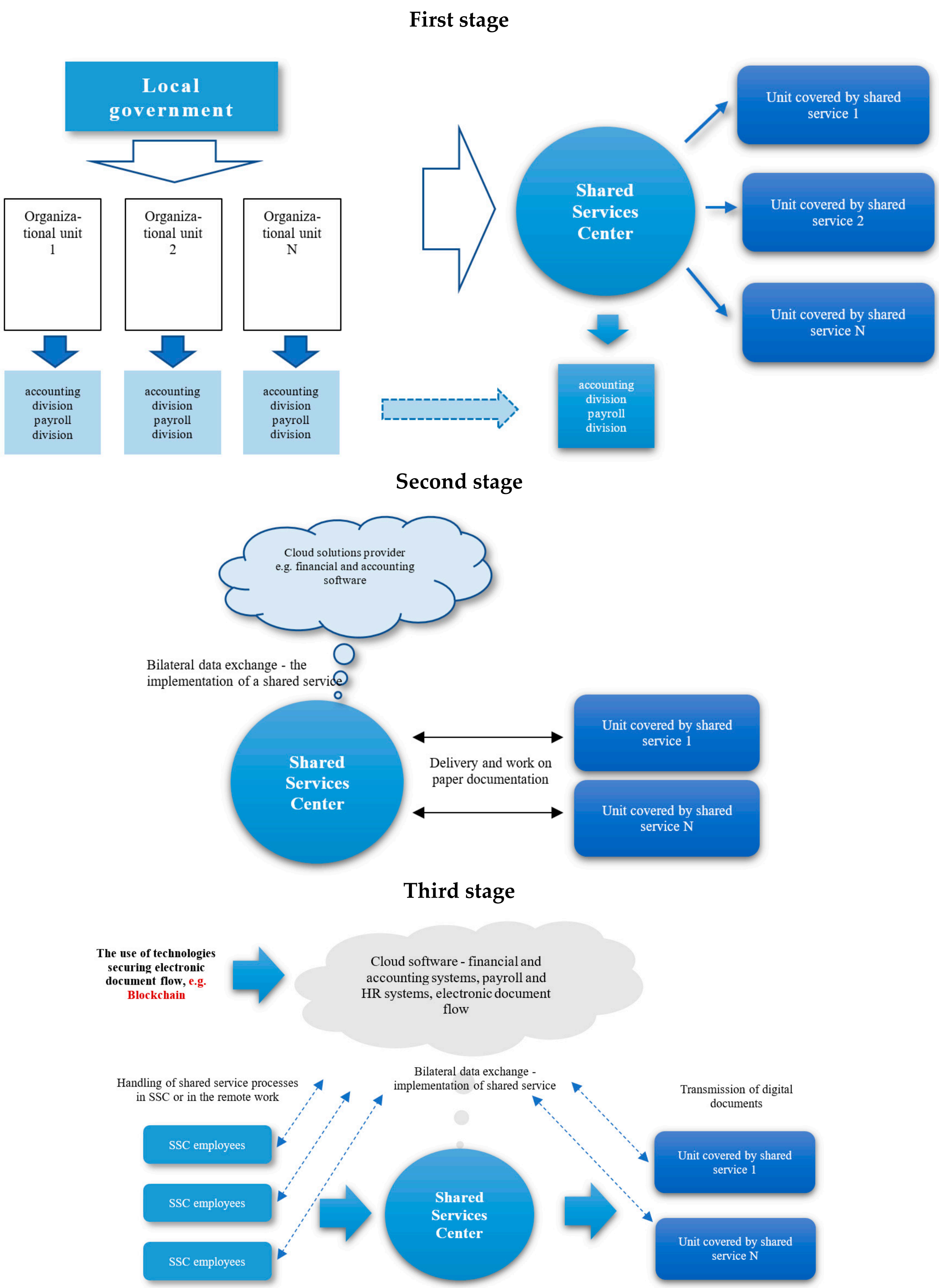


**Figure 4.** The process of creating local government shared services centers in Poland. Source: own study based on the conducted research.

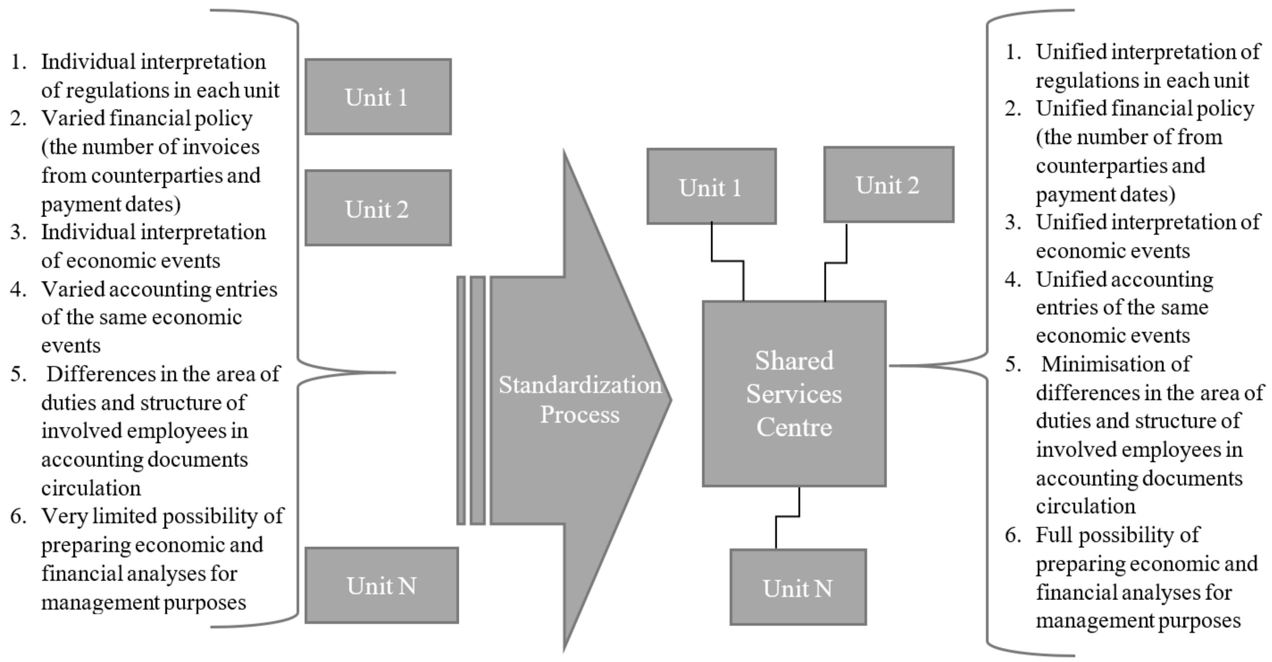


**Figure 5.** The scope and effects of accounting processes standardization in local government shared services centers (the example of an SSC in the city of Toruń, Poland). Source: Modrzyński, P., Karaszewski, R., Reuben, A. (2018), p. 69 [53].

### *2.4. SSC in Elbląg, Poland—A Case Study*

The process of creating an SSC in Elbląg began in 2019, and the unit began providing shared services at the beginning of April 2020. The scope of subjects that are serviced includes all educational units (61 units in total), and the scope of the provided shared services currently includes mainly financial and accounting, payroll, tax and reporting services for the units supported [61]. Such a range of activities and services for so many organizational units of the municipality is associated with generating and sharing a very large number of documents. In traditional handling, paper documents are delivered to the SSC and from the SSC to the units served. Therefore, such a solution is highly ineffective, costly, time-consuming and labor-intensive, and may involve access to sensitive data unauthorized persons in the event of, e.g., loss of a document during its transport. The first nine months of operation of the SSC in Elbląg shows the scale of this unit's operations: 14,600 purchase invoices and 1800 payroll documents for employees of units covered by shared services. The organization of an SSC with the use of cloud-based software solutions and electronic circulation and approval of financial, accounting and payroll documents (Figure 4, second and third stage) is of a key importance. The implementation of digital document workflow together with the common service standardization process allows one to reduce the labor intensity of the processes carried out. The example of an SSC in the city of Toruń (a unit operating since 2017 and with a similar scope of personal and object service) shows the level of the number of documents generated by the serviced units and SSC related only to the main processes of shared services: accounting and payroll (Figure 6). The authorities of the city of Elbląg decided to organize shared services processes in the SSC delivered on stage 3 (Figure 4) from the beginning, i.e., based on electronic document flow and transaction approval using blockchain technology. Such a solution, in which the shared service process was based on electronic document circulation, allowed them to achieve the planned economic results: reduction of employment costs by approximately 10% [62]. The aspect of energy efficiency, or in a broader perspective, ecology, discussed in this article, can be presented as a derivative of savings in material consumption: i.e., a reduction of $CO_2$ emissions by eliminating the need to produce and transport paper documents to and from the SSC and reducing the consumption of office materials (paper, toners, document covers, etc.).

Presenting the data on the number of supported accounting or payroll processes, which constitute the pillar of the shared service provided by local government SSCs in Poland, as well as in the analyzed SSC example in the city of Elbląg, it can be noted that the greatest labor consumption is related to collecting, processing, recording and archiving transactions (data, postings, transfers, etc.). Improving the efficiency and security of SSCs operations requires the optimization of the above processes, and this is where blockchain technology comes in handy.

Handling a large number of processes carried out for units covered by shared service is a common challenge for every SSC and here blockchain technology can offer a helping hand. It allows for quick settlement of transactions, as it automates the data validation process, and thus reduces the costs of their implementation. Additionally, blockchain offers many possibilities in the Procure-to-Pay (P2P) and Supply Chain process. In a P2P process, where a blockchain is used to digitize and automate the entire shared service process, from ordering to invoicing and payment, the entire process can be supported and immediately activated thanks to this technology. Basing the communication process of financial and accounting systems on blockchain technology also enables the automation of the reconciliation process, for example: balances with contractors [63,64].

Given the scale of transactions carried out by SSCs, the introduction of blockchain technology to secure them is crucial not only in terms of ensuring the security of the process itself, but also in terms of increasing the effectiveness of the unit's operation (Figure 7) [65].

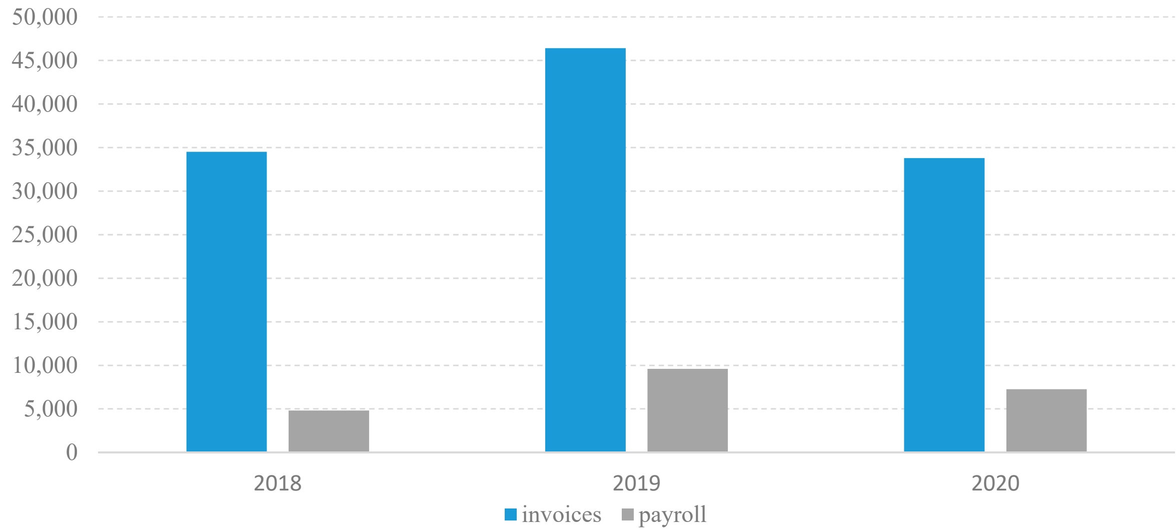


**Figure 6.** Number of financial, accounting and payroll documents generated in one of Polish SSCs. Source: own study based on data gathered in one of Polish SSCs.

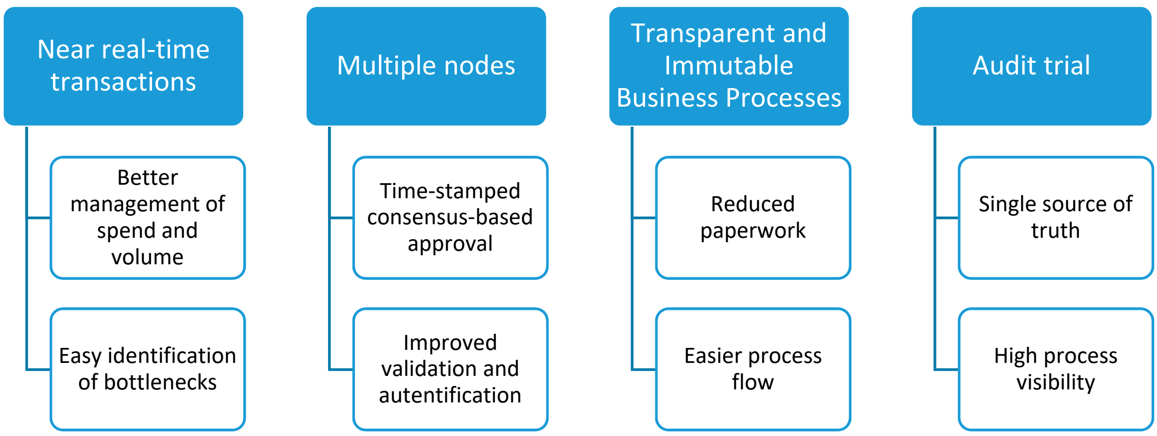


**Figure 7.** Benefits of blockchain technology. Source: Lakshmi and Sricharan, 2019, p. 1785 [29].

The implementation of blockchain technology in SSCs enables complete digitization of the service provided and thus reduces the consumption of office supplies and activities related to document transport to the necessary minimum [66–69]. The essence of shared services in the area of accounting, payroll and taxation is providing fast and efficient document flow. Standardization of this process is one of the elements of increasing the effectiveness of SSCs. The second area of improving the efficiency of SSCs is related to the digitization and securing of its activities, including through the use of blockchain technology, which allows to reduce the costs of shared services, ensures greater security of implemented processes and enables increasing energy efficiency. It has to be emphasized that the role of blockchain technology in the process of increasing the efficiency of functioning and the legitimacy of its use by SSC is of key importance. It has to be clearly stated that it is not possible to increase the effectiveness of these units without the use of electronic and properly secured document flow (which, among other things, allows the costs of transport and unit maintenance to be reduced). The role of blockchain technology in the process of increasing the efficiency of SSCs is at least twofold. First of all, it allows one to secure mass transactions and shared service processes. Furthermore, by eliminating the need to physically produce and deliver paper documents, an additional, positive aspect of using this technology is introduced: broadly defined environmental efficiency. Research questions presented in the article perfectly fit into the discussion on the possibilities of widespread use of blockchain technology in the public sector, both at the state and local government units level. These possibilities are confirmed by the already existing applications using blockchain technology, e.g., in the financial sector, which resulted, inter alia, in the elimination of intermediary transactions and led to a reduction in the costs of implemented processes—which appears also in the case of joint service provided, inter alia, by SSCs [70].

In order to calculate the effect of reducing $CO_2$ emissions resulting from the implementation of electronic document circulation by SSC in Elbląg, the applicable EU standards and guidelines should be taken into account. On 17 April 2019, the European Parliament and the Council adopted a regulation (EC No 443/2009 and EU No 510/2011) setting $CO_2$ emission standards for new passenger cars and new vans in the EU [71]. This regulation entered into force on 1 January 2020, replacing and repealing Regulations (EC) 443/2009 (cars) and (EU) 510/2011 (vans). To achieve so-called climate neutrality in 2050, the EU has planned to achieve the intermediate target of a net reduction of greenhouse gas emissions by at least 55% by 2030 (compared to 1990) [71]. The average level of $CO_2$ emissions in recent years has remained constant in the EU and individual Member States, which is related to the increasing number of cars used, despite the use of increasingly green engines. It is worth emphasizing that these figures show that Poland and Germany are the countries with the highest level of $CO_2$ emissions (Table 1).

It is also worth noting that the level of pollution generated by transport vehicles places Poland in the group of the EU countries with the lowest air quality (Figure 8).

A very high level of $CO_2$ emissions and air pollutants related to road transport places Poland at the forefront of the EU member states, where environmental protection and implementation of solutions increasing energy efficiency should be a priority. On 1 January 2020, new EU regulations came into force regarding exhaust emission standards for new passenger cars, according to which car manufacturers must comply with the average $CO_2$ emission limit per car of 0.95 g/km [71].

Based on the address data of units covered by shared services delivered by the SSC in Elbląg, the total distance can be determined, which will be the basis for calculating the effectiveness of $CO_2$ emission reduction while eliminating the transport of documents. The total distance of the units served from the SSC in Elbląg is 151.7 km, which, assuming that documents are transported only once a week (in fact, documents are transported several times a week, and in some cases, even on a daily basis), gives a total distance of 606.8 km per month and 7281.6 km per year. Taking into account the $CO_2$ emission standards that are currently binding in the EU member states, the transport of documents necessary for efficient operation of the SSC in Elbląg would generate 691.6 kg of $CO_2$ emissions annually, not counting the carbon footprint associated with the production of fuel used by cars used for transport.

**Table 1.** Average $CO_2$ emissions per km (new passenger cars).

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| European Union | 139.6 | 135.3 | 132.0 | 126.4 | 123.1 | 119.1 | 117.6 | 118.0 | 119.6 |
| Belgium | 133.4 | 127.2 | 128.0 | 124.0 | 121.3 | 117.9 | 115.9 | 115.9 | 119.4 |
| Denmark | 126.2 | 125.0 | 117.0 | 112.7 | 110.2 | 106.2 | 106.0 | 107.1 | 109.5 |
| Germany | 151.1 | 145.6 | 141.6 | 136.1 | 132.5 | 128.3 | 126.9 | 127.2 | 129.5 |
| Greece | 143.7 | 132.7 | 121.1 | 111.9 | 108.2 | 106.4 | 106.3 | 108.8 | 111.1 |
| Spain | 137.9 | 133.8 | 128.7 | 122.4 | 118.6 | 115.3 | 114.4 | 115.0 | 118.1 |
| France | 130.5 | 127.7 | 124.4 | 117.4 | 114.2 | 111.0 | 109.8 | 110.4 | 112.1 |
| Italy | 132.7 | 129.6 | 126.2 | 121.1 | 118.1 | 115.2 | 113.3 | 113.3 | 115.6 |
| Hungary | 147.4 | 141.6 | 140.8 | 134.4 | 133.0 | 129.6 | 125.9 | 125.6 | 129.0 |
| Netherlands | 135.8 | 126.1 | 118.6 | 109.1 | 107.3 | 101.2 | 105.9 | 108.3 | 105.5 |
| Austria | 144.0 | 138.7 | 135.7 | 131.6 | 128.5 | 123.7 | 120.4 | 120.7 | 123.1 |
| Poland | 146.2 | 144.5 | 141.3 | 138.1 | 132.9 | 129.3 | 125.8 | 127.6 | 127.8 |
| Portugal | 127.2 | 122.8 | 117.6 | 112.2 | 108.8 | 105.7 | 104.7 | 104.7 | 106.1 |
| Sweden | 151.3 | 141.8 | 135.9 | 133.2 | 131.0 | 126.3 | 123.1 | 122.3 | 122.2 |
| United Kingdom | 144.2 | 138.0 | 132.9 | 128.3 | 124.6 | 121.3 | 120.1 | 121.1 | 124.7 |

Source: European Environment Agency (EEA), European Commission—Directorate-General for Climate Action (DG CLIMA), Eurostat, access dated on 5 January 2021.

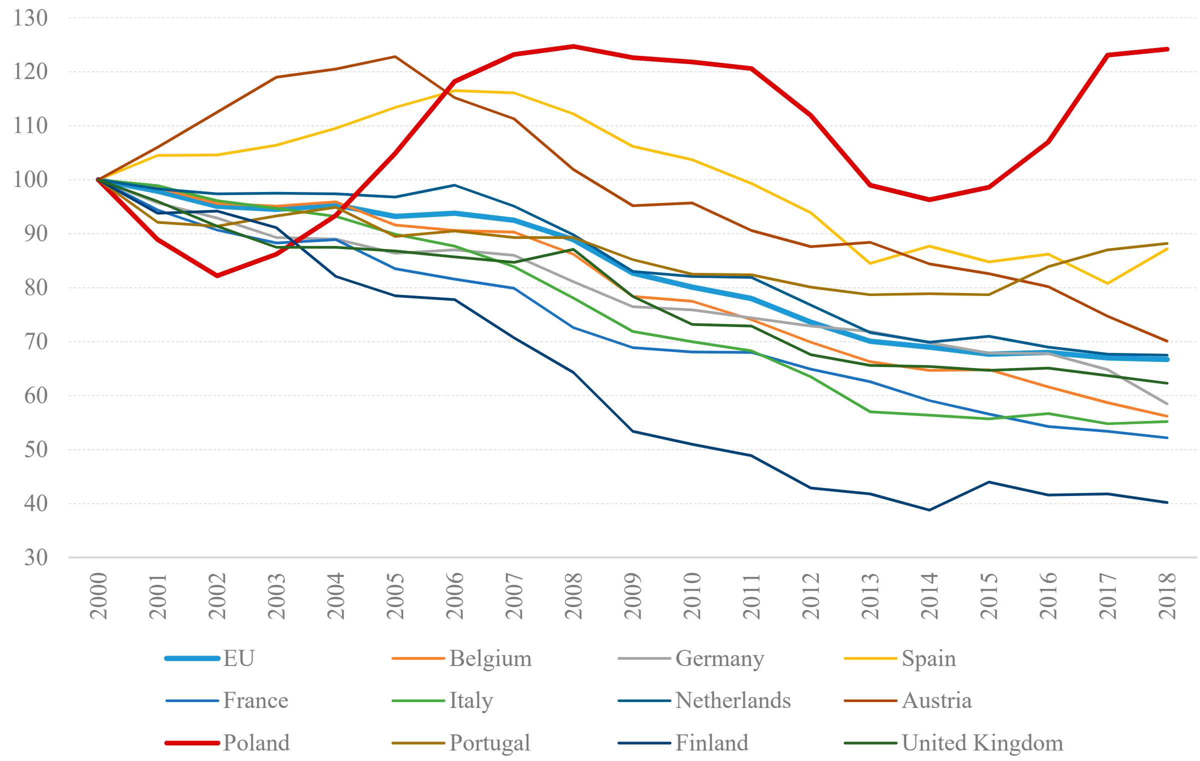


**Figure 8.** Pollutant emissions from transport (year 2000 = 100%) Source: European Environment Agency (EEA), Eurostat, accessed on 5 January 2021.

Calculating the demand for paper consumption only for the implementation of two basic areas of the shared service provided by the SSC, we obtain 14,600 invoices and 1800 payroll lists, which, assuming an average of 5 pages for one payroll, gives a total of 23,600 sheets of paper, which gives 47.2 reams of paper. Based on the wood consumption standards for the production of one ream of paper [72], it can be estimated that the minimum consumption of paper for the needs of only one SSC in Elbląg is equivalent to cutting at least 4 adult trees per year. It is worth remembering that office supplies used in standard service include not only paper, but also stationery, toners, document sleeves or electricity necessary for printing documents, which means that total $CO_2$ emissions into the atmosphere are, in fact, at a much higher level. If one look at the problem more broadly and takes into account the entire process, i.e., the production of office materials, their use and subsequent disposal, along with the elements necessary for the physical transport of documents, and multiply by the number of SSCs in Poland, Europe or the world, it turns out that the obtained figures are enough incentive to immediately start actions aimed at the massive use of blockchain technology in the SSCs reality.

Extrapolating the results of services provided by the SSC in Elbląg to the entire sector of local government shared service centers in Poland, the data contained in reports prepared jointly with the Union of Polish Metropolises [50] (associating the 12 largest agglomerations) and the Association of Polish Poviats [73] should be additionally used. In particular, the analysis of the number of generated documents by other SSCs operating in Polish cities is required [74]. The results of the research of the local government shared services sector indicate that such units operate in 80% of the largest Polish cities and in nearly 30% of poviats. The average number of units serviced by SSC operating in the largest cities is 146 units, and the average number of invoices generated by 1 unit covered by the shared service ranges from 50 to 56 such documents. Shared Service Centers operating in smaller communes are more diverse, and the number of serviced units is on average 12 entities. The scale of accounting documents in local government units is similar in each commune and results from their specificity; therefore, averaged data (50–56 invoices) can be used to calculate the number of invoices (Table 2).

The estimated number of invoices handled by the local government SSCs operating in Poland is within a monthly range from 126.7 thousand up to 142.0 thousand invoices, which gives as many as 1.7 million invoices per year (based on the number of the local government SSCs in Poland and the average number of units served [50,73]). In addition, it should be emphasized that in the accounting flow, apart from invoices, there are other documents circulating, such as accounting notes, applications for engagements, bills, bank statements and others. For that reason, the scale of labor intensity of a shared service and circulation of paper documents is actually at much higher level. Therefore, adding the payroll to other documents (on average 2.21 payroll list per 1 serviced unit and 5 pages per 1 payroll), 1.771 million pages are received on an annual basis, which makes 3542 reams of paper in total—the equivalent of over 300 adult trees annually only in Poland and only as a result of local government SSCs creation. In a similar way, it is also possible to extrapolate savings resulting from the reduction of transport costs, and thus, $CO_2$ emissions. The value of $CO_2$ reduction was calculated on the basis of the following parameters: (1) the average distance between the units under shared service and the SSC, which is 2.53 km, (2) the number of local government SSCs operating in Poland and (3) the average number of units under shared service [50,73]. Therefore, taking into account the presented parameters, it can be calculated that, assuming the transport of documents from the serviced unit to the SSC occurs only once a week, a total distance of 2865.24 km is achieved, which gives as much as 307,517.57 km on an annual basis. Taking into account the data on $CO_2$ emissions, we get the opportunity to reduce emissions at the level of 29,702.75 kg of $CO_2$ per year.

**Table 2.** Calculation of the average number of invoices per 1 supported unit (based on the number of invoices generated by units in a given year).

| Shared Services Center | Month | | | | | | | | | | | | Average Number of Purchase Invoices | The Number of Supported Unit | The Number of Purchase Invoices Per Unit Supported |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | | |
| SSC 1 | 4441 | 5870 | 6905 | 6154 | 7269 | 6256 | 4168 | 4850 | 6371 | 8269 | 9209 | 10,224 | 6666 | 133 | 50.1 |
| SSC 2 | 3418 | 3338 | 4384 | 3797 | 3962 | 3597 | 2100 | 2536 | 4143 | 4311 | 4339 | 6028 | 3829 | 69 | 55.5 |
| SSC 3 | 2269 | 2719 | 3620 | 3120 | 3428 | 3276 | 2380 | 2257 | 3841 | 4128 | 4597 | 5385 | 3418 | 61 | 56.0 |
| SSC 4 | 2356 | 3357 | 3698 | 3365 | 3856 | 3352 | 3128 | 2929 | 5753 | 4256 | 4578 | 6183 | 3901 | 69 | 56.5 |
| SSC 5 | 10,078 | 12,960 | 15,408 | 12,891 | 16,380 | 14,057 | 9305 | 9215 | 14,109 | 18,645 | 19,864 | 22,950 | 14,655 | 276 | 53.1 |
| SSC 6 | 2974 | 3219 | 4501 | 3147 | 3651 | 3874 | 2479 | 2567 | 4671 | 4960 | 4570 | 4644 | 3771 | 68 | 55.5 |

Source: own study based on audits of selected local government Shared Service Centers.

*2.5. Modern Technologies—A Tool to Increase Efficiency and Costs/Energy Reduction*

A modern approach to management allows one to combine the tools of economic efficiency and process and technological efficiency with pro-ecological solutions. This tripod of solutions perfectly fits current trends and needs to be reflected in EU legislation and contemporary management theories. The role of the public sector in the area of impact on energy efficiency is special, because it acts both as an entity creating the policy of financing projects that fit into the energy efficiency trend, and as a beneficiary of such programs. The presented project of creating SSCs in local government structures and the use of blockchain technology to secure the transaction of digitally provided shared services is an example of a broad approach not only to the issues of modern management or ensuring the creation of a successful data-driven society, but also to the issues of improving the ecological image of the municipality by reducing transport needs and use of office supplies, and thus, $CO_2$ emissions. Reducing the consumption of office supplies to the necessary minimum and eliminating the costs of transporting documents (and thus, carbon footprint left behind) are the foundations for improving the efficiency of public sector units, which fits directly into the idea of New Public Management or New Public Governance [75] (p. 334).

The presented case-study of SSC in Elbląg is in line with global trends on the shared services market operating in the private sector, where a huge emphasis is currently placed on the key aspects allowing further sustainable development related to the automation of the processes provided, increasing their efficiency and developing the concept of corporate social responsibility. Nowadays, these are the activities that are more and more commonly implemented in the public sector as well [58,65]. The dynamics of the development of the local government shared services sector and the scale of conducted activity indicate that in order to achieve the assumed management efficiency and economic efficiency indicators, electronic document flow is no longer a vision of the future, but a current urgent need. The use of blockchain technology will allow us, on the one hand, to secure transactions carried out on a large scale, and on the other hand, it will contribute to increasing energy and environmental efficiency.

It has to be emphasized that there are other studies already conducted confirming that modern cloud solutions based, for example, on SDN/NFV technologies, allow for savings of 40–80% energy compared to 4G routers. This is another argument supporting the need to move away from anachronistic paper solutions and use of individual local servers in favor of cloud solutions based on innovative tools ensuring cost reductions and energy savings [31].

## 3. Conclusions

The transition from the times of hard copies to the era of digitization means not only reducing the above mentioned paper consumption or need to transport paper documents, and thus, reduction of the carbon footprint. Digital documents also create the carbon footprint, but its scale is considerably smaller for at least several reasons. It is a fact that digital documents require modern equipment, server rooms require proper air conditions and modern computer equipment requires energy and components to use it. Audits and research conducted in the Polish local government SSCs showed that the equipment (computer, printers, local servers, etc.) used before the creation of SSCs was in many cases very old, and therefore consumed much more energy than modern computers. At the moment, creating an SSC is a perfect example how economies of scale should be used. The case study of the SSC in Elbląg proves that: (1) fewer employees use fewer computers, network printers are used instead of individual ones, and (2) minimized—and in some cases completely eliminated—is the need to generate and deliver paper documents (reduction of fuel consumption and $CO_2$ emissions). In addition, modern cloud storage servers use "worm" technology, which enables better compression of the disk space than before, and thus, greater possibilities of storage digital documents with much greater energy efficiency.

When answering the research questions posed at the beginning of this article, it has to be emphasized that it should be noted that all the answers to the questions are positive. When questions 1 and 2 are considered, it should be noted that it is possible to achieve noticeable effects of broadly understood energy efficiency in the case of SSCs provided that they are new type SSCs—a 2nd generation SSC—using modern technologies, e.g., blockchain. Creating a new type of SSC or introducing organizational changes that are of key importance to the existing ones and allow for their modernization through the use of big data aggregation, cloud storage and secure data sharing is a necessity of modern times, and a requirement of the New Deal on Data. The use of modern tools facilitating SSCs of the second generation should be on the list of priorities and challenges of modern SSCs, and increasing energy efficiency is one of the key elements allowing one to increase the efficiency and competitiveness of each SSC, and ensure participation in the global effort of slowing down unfavorable climate change. Regarding research question No. 3, it has to be emphasized that improving energy efficiency is not just a matter of image building or costs saving, although each of these reasons is undoubtedly very important. The authors of this article tried to show that blockchain technology is a tool that perfectly allows one to achieve not only economic or organizational goals but also allows one to participate in the process of changing the way of thinking and attitudes of Polish local governments on an unprecedented scale.

Moreover, it has to be emphasized that the key to the success of modern society is not only ensuring that data are aggregated, but awareness that data are worth more when shared. Shared and aggregate data lead to creating a modern society and provide features that are essential, especially in times of pandemic, thanks to the possibility of sharing information online without physical contact and the possibility of continuing work by SSC employees in home office mode while ensuring the maximum level of security thanks to the use of blockchain technology. If all kinds of savings related to the limited use of office materials and a very limited need to use means of transport are added to this, it turns out that the use of blockchain technology and cloud solutions facilitates and improves not only the aggregation of data and secured access to it, but also has a huge impact on the reduction of $CO_2$ emissions and reduces the carbon footprint of SSCs. This (on the one hand) side and (on the other) extremely positive effect of using blockchain technology in the work of SSCs has a great chance to become part of a larger puzzle already in the near future.

**Author Contributions:** Conceptualization, R.K. and P.M.; Methodology, R.K., P.M. and J.M.; Project administration, P.M. and J.M.; Resources, P.M.; Supervision, R.K.; Writing—original draft, R.K., P.M. and J.M.; Writing—review & editing, R.K., P.M. and J.M. All authors have read and agreed to the published version of the manuscript.

**Funding:** This work was not supported by any external source. The authors take all responsibility to prepare and conduct research.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Table 1—publicly available datasets were analyzed in this study. This data can be found here: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sdg_12_30&lang=en, accessed on 24 January 2021. The data presented in Table 2. are available on request from the corresponding author. The data are not publicly available due to privacy restrictions. The data presented in Figure 6. are available on request from the corresponding author. The data are not publicly available due to privacy restrictions. Figure 8—publicly available datasets were analyzed in this study. This data can be found here: https://ec.europa.eu/eurostat/databrowser/view/t2020_rk300/default/table?lang=en, accessed on 24 January 2021.

**Acknowledgments:** Disclosure statement: No potential conflict of interest was reported by the authors. Notes on contributors: Robert Karaszewski—Full Professor, Director of MBA Program AACSB, AMBA, hr accredited, Head of Business Excellence Department Nicolaus Copernicus University

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**Conflicts of Interest:** The authors declare no conflict of interest.

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