energies

MDPI

Article

Management of Waste Batteries and Accumulators: Quest of European Union Goals

Zbysław Dobrowolski [1,*], Łukasz Sułkowski [1] and Wiesław Danielak [2]

[1] Institute of Public Affairs, Jagiellonian University, 31-007 Kraków, Poland; lukasz.sulkowski@uj.edu.pl
[2] Institute of Management and Quality Sciences, University of Zielona Góra, 65-417 Zielona Góra, Poland; w.danielak@wez.uz.zgora.pl
* Correspondence: zbyslaw.dobrowolski@uj.edu.pl

Abstract: Energy issues are multifaceted and are not limited to power plants, biogas plants or transmission lines. They also include the production, usage and utilisation of batteries and accumulators, which are increasingly valuable due to, among other things, the decision to develop the production of electric cars. This article creates new ground by analysing the European Union management system of batteries and accumulators in the cause–effect context. This paper's insights have emerged iteratively based on the theory reviewed and the empirical case—a deep analysis of the Polish management system of batteries and accumulators. The findings show that the public institutions in the analysed European Union Member State—Poland—were not ready to create a fully coherent and effective oversight system on managing batteries and accumulators. It may limit the reliability of the European Union's reporting on battery and accumulator management, which is a part of the European energy policy. The findings make two main contributions: first, they contribute to developing a theory of energy resource management; second, this article contributes to a further contextual diagnosis of the comprehensive management system of waste batteries and accumulators, which is an important part of the European Battery Alliance. Moreover, the avenues for further research emerged from the present study.

Keywords: energy; batteries and accumulators; European Union; waste; energy resources management

Citation: Dobrowolski, Z.; Sułkowski, Ł.; Danielak, W. Management of Waste Batteries and Accumulators: Quest of European Union Goals. *Energies* **2021**, *14*, 6273. https://doi.org/10.3390/en14196273

Academic Editors: Magdalena Ziolo, Diana-Mihaela Țîrcă and Isabel Novo-Corti

Received: 10 July 2021
Accepted: 29 September 2021
Published: 1 October 2021

1. Introduction

The development of modern technologies that make life easier for people causes various environmental threats to human health. Heavy metals, such as lead, cadmium or mercury, and electrolytes are hazardous not only for people. Simultaneously, the electric cars industry is growing to create the batteries and accumulators market. Its rapid growth is limited by low resources—rare earth metals.

Interestingly, the scientific literature on the energy management of waste batteries and accumulators is limited. In terms of the energy sector, researchers primarily focus on increasing the technical performance of energy devices. They also show that barriers to energy efficiency in the studied sectors, such as the cost and risk of production disruptions, lack of access to capital funding, lack of submetering, play an essential role in explaining why cost-effective energy investments have not been implemented [1–10]. We define energy management as the process to achieve energy efficiency through the efficient usage of resources. This term is related to any organisational activity linked with energy production, storage and use, including energy from batteries and accumulators. Similar to the European Battery Alliance, we perceive the necessity to implement the sustainable battery value chain in Europe, which includes the competitive recycling of batteries and accumulators [11].

Taking into account the growing importance of batteries and accumulators production and usage, the Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators

and the repealing Directive 91/157/EEC (*Journal of Laws* EU.L.2006.266.1 of 2006.09.26) imposed on the Member States of the European Union (EU) several obligations to undertake activities and introduced national regulations aimed at the managing of the waste batteries and accumulators. The European Union Member States are obliged, among other things, to introduce a collection and disposal system for waste batteries and accumulators based on the "polluter pays" principle.

Despite some studies on the energy management of batteries and accumulators [12–20], there is a research gap regarding how the EU Member States implement Directive 2006/66/EC provisions. We also point out, similar to Thomann and Sager [21], that although the compliance of Member States' activities with the EU policies and laws is the subject of many studies, the research is often characterised by a strong focus on the legal conformance with the EU, e.g., [22,23]. However, this focus is insufficiently accounting for the implications of the EU's multilevel governance structure. It may lead to an incomplete picture of the EU implementation caused by its diversity and practice [21].

The study of the Polish system of managing batteries and accumulators fill the above gap and contribute to further in-depth research on this problem. Moreover, the recently published study on the Polish management system of batteries and accumulators only presented the system's regulations [24,25]. This research goes much further, and it shows how this system works in practice and the causes of its malfunction. Based on a literature review and documents from audits carried out by the Polish Supreme Audit Institution, we aim at answering the following research questions: (1) What was the result of conducting information and education campaigns to convince Poles of the European Union Directive requirements? (2) What was the effectiveness of creating a system for collecting used batteries and used accumulators? (3) What was the effectiveness of the supervision of public institutions over waste battery and accumulator collectors? (4) Did the entities operating in the battery and accumulator management system reliably fulfil the analytical and reporting obligations? The last research question is particularly important. Any lack of reliability in Polish reporting may limit the reliability of the European Union reporting on battery and accumulator management, part of the European energy system.

The findings have several implications. They help modify the management system, which minimises the negative influence of batteries and accumulators on the environment and enables the recovery of valuable resources essential for the energy system.

The paper proceeds as follows: First, we show the legal framework of managing batteries and accumulators. Next, we provide evidence that the current system did not operate appropriately, presented by the cause–effect model. Finally, we formulate conclusions and point out opportunities for further research.

2. Materials and Methods

Our study covered the Polish management system for waste batteries and accumulators. The research used methods and techniques appropriate for the management discipline, applying the epistemological pluralism strategy [26,27] and seeking the most probable explanations of facts [28]. Considering the Eckstein typology [29], our research performed descriptive and explanatory functions of scientific cognition.

First, we based our study on a literature review. We analysed the literature from the Google Scholar database, taking into account the thematic scope of our research. From the 130 publications analysed, we chose the ones presented in this article, which helped to better understand the aim and research problem. We assumed that the literature review could inspire the study, as Nordqvist, Gardner, Short and Payne underlined [30,31]. Second, we also analysed the EU Directive 2006/66/EC and the Polish legal norms, which describe how to organise the batteries and accumulators management system. Third, we also reviewed the European Commission reports on implementing Directive 2006/66/EC. We reviewed laws, regulations and EU documents to show the importance of batteries and accumulators management for the European Union policy related to this segment of the energy market and its rare earth recovery policies.

Treib [32] aptly notes that the European Union is marked by a highly decentralised implementation structure that leaves the Member States responsible for policy execution. Treib also aptly states that the interest of the EU Member States is not homogeneous. This fact and the high consensus requirements influence the performance of the EU policies. The EU leaves specific issues to the discretion of Member States to facilitate agreement. Therefore, we assumed that the supreme audit institution (SAI) in each Member State should evaluate how States implement EU policies and regulations, including the EU Directive about the system of waste batteries and accumulators management. We aimed to determine the extent to which the supreme audit institutions from the EU member states examined the management system of used batteries and accumulators. Due to their unique position in the state structures, SAIs have a broad auditing authority [33–36]. They may independently confirm whether public administration is ready to create a fully coherent and effective oversight system on managing batteries and accumulators system.

It is significant for the reliability of the European Union reporting on battery and accumulators management, being a part of the European energy system. This reporting system is based on data provided by the EU Member States [37]. Therefore, there is a need to review and evaluate these data by SAIs, which are subordinate only to parliaments of the EU Member Stated and independent to executive branches of the EU Member States.

In sum, we decided to analyse the published SAIs' audit reports, and we analysed the websites of supreme audit institutions from all the EU Member States to determine how these organisations examined the implementation of Directive 2006/66/EC in their countries. Based on this analysis, we found that only the Polish SAI audited the waste batteries and accumulators system. We analysed the Polish SAI audit reports and SAI's final audit report sent to the Polish parliament (SAI analysed the activities of 19 key public entities in the management of the Polish system of batteries and accumulators in the year 2015–2016 and the first half of 2017 and earlier years when it was necessary to conduct comprehensive assessments of the system's functioning under examination).

3. Results and Discussion

3.1. The Legal Framework of the Management System of Batteries and Accumulators in the European Union and Its Member State—Poland

The development of modern technologies causes various threats to the environment and human health. Heavy metals and electrolytes contained in batteries and accumulators are particularly dangerous. The EU industry produces 15 percent of the global production of lead–acid batteries, similar to the EU's contribution to the global GDP (16–17 percent). The EU is a net exporter of this type of battery. The opposite situation is in the production of other types of batteries. The EU is a net importer of NiCd (nickel–cadmium), NiMH (nickel–metal hydride), and lithium-based batteries. The volume of NiCd, NiMH and lithium-based batteries manufactured in the EU is around 5 percent of the global output [38,39]. The European Commission notes that "approximately 800,000 tons of automotive batteries, 190,000 tons of industrial batteries, and 160,000 tons of consumer batteries enter the European Union" every year [31]. The European Commission points out that not all of these batteries are properly collected and recycled at the end of their lives, increasing "the risk of releasing hazardous substances and constitutes a waste of resources. Many of the components of these batteries and accumulators could be recycled, avoiding the release of hazardous substances to the environment and, in addition, providing valuable materials to important products and production processes in Europe" [38,39]. Therefore, and due to the need to recover valuable metals, regulations have been introduced in the European Union that define how to manage waste batteries and accumulators. Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006, imposed several obligations on the EU Member States in this regard and obliged them to introduce national regulations to minimise the negative impact of batteries and accumulators on the environment. The EU Member States were obliged, among other things, to introduce a collection and disposal system for waste batteries and accumulators based on the "polluter pays" principle, creating conditions for consumers to dispose of waste batteries and accu-

mulators at specified locations quickly and free of charge. The Directive 2006/66/EC also introduced an obligation for the EU Member States to monitor collection rates for portable waste batteries and spent portable batteries and report on the collected collection rates annually. The Directive 2006/66/EC was based on Art. 175 sec. 1 of the Treaty establishing the European Community. The Directive 2006/66/EC also indicates Art. 95 sec. 1 of the Treaty as a basis for harmonising the requirements and labelling of heavy metals in batteries and accumulators; thus, ensuring the smooth functioning of the internal market and avoiding distortions of competition within the European Community. The EU Member States were committed to a minimum collection rate of 25 percent by 26 September 2012, and 45 percent by 26 September 2016.

The above discussed Directive requires that the European Commission, assisted by the EU Member States, develop some of its provisions in detail. For example, Commission Decision 2008/763/EC establishes pursuant to Directive 2006/66/EC of the European Parliament and the Council, a common methodology for the calculation of annual sales of portable batteries and accumulators to end-users; Commission Decision 2009/851/EC establishes a questionnaire for the Member States reports on the implementation of Directive 2006/66/EC of the European Parliament and the Council on batteries and accumulators and waste batteries and accumulators; Commission Regulation (EU) No 1103/2010 establishes pursuant to Directive 2006/66/EC of the European Parliament and the Council, rules as regards to the capacity labelling of portable secondary (rechargeable) and automotive batteries and accumulators; Commission Regulation (EU) No 493/2012 of 11 June 2012 lays down, pursuant to Directive 2006/66/EC of the European Parliament and the Council, detailed rules regarding the calculation of recycling efficiencies of the recycling processes of waste batteries and accumulators.

With the adoption of Directive 2006/66/EC, the European Battery Alliance was launched in 2017 by the European Commission, EU countries, the industry, and the scientific community. One may seek the roots of this initiative in the following statement: batteries became a strategic part of Europe's clean and digital transition and critical enabling technology, essential to the automotive sector's competitiveness. Therefore, the European Commission aims to make Europe a global leader in sustainable battery production and use [11].

By now, supported by the European Commission and the European Investment Bank, the European Battery Alliance brings together more than 440 key industrial and innovation players in the battery value chain [11]. In 2018, the European Commission set a strategic action plan for batteries, which aims, among others, to secure access to raw materials, among others, through recycling in a circular economy of batteries [40]. The European Commission points out that Europe had almost no battery cell manufacturing at scale when launching the alliance. Europe only accounted for around 3 percent of the world market and faced a future with a mostly foreign-supplier-dependent EU. Around EUR 100 billion in investment commitments should change this situation. Following the European Green Deal, the Circular Economy Action Plan and the Industrial Strategy, the EU has been working on a competitive, circular, sustainable and safe value chain for all batteries placed on the EU market [11].

Directive 2006/66/EC was implemented into the Polish legal system by the Act of 24 April 2009, on batteries and accumulators (*Journal of Laws* of 2020, item 1850) (ABA).

The Act specifies:

- Requirements for batteries and accumulators placed on the market;
- Rules for placing batteries and accumulators on the market;
- Rules for the collection, processing, recycling and disposal of waste batteries and accumulators.

The purpose of the Act was to:

- Reduce the negative impact of batteries and accumulators as well as waste batteries and accumulators on the environment by reducing the number of hazardous substances in batteries and accumulators and the proper collection and recycling of waste

generated from them, including supporting a high level of collection of portable waste batteries and waste portable accumulators;
- Harmonize the requirements concerning the content of heavy metals in batteries and accumulators and the requirements for their labelling;
- Ensure the smooth functioning of the internal market and avoid distortions of competition within the European Union.

The Act regulates the rights and obligations of entities: (1) placing batteries or accumulators on the market; (2) distributing batteries or accumulators or equipment; (3) collecting, processing, recycling or disposing of waste batteries or accumulators; (4) using batteries or accumulators.

ABA assumes that entrepreneurs placing batteries and accumulators on the market or other products that include a battery or accumulator are responsible for waste management in the form of waste batteries and accumulators. End users should hand over collected waste portable batteries and accumulators to collection points (adapted containers located in educational and commercial institutions, post offices, administration offices, etc.). Moreover, used batteries and used car and industrial accumulators should be returned to retailers or wholesalers of batteries and accumulators. Then, these firms deliver them to the operators of waste batteries and accumulators treatment plants, where they can be recycled or utilised.

3.2. Implementation of Directive 2006/66/EC in the EU Member States. Official Data and Reality

The evaluation of the EU Directive 2006/66/EC on batteries and accumulators (the Batteries Directive), which is the only piece of EU legislation entirely dedicated to batteries, was completed by the European Commission in 2019. The evaluation report of the Batteries Directive was published on the 9 April 2019. The European Commission concluded that the Directive has positive results on the environment, promoting recycling and the better functioning of the internal market for batteries and recycled materials [38,39,41].

The European Commission's key source of information was the details on collection rates and efficiencies submitted by the Member States [38]. It made sense to rely on data provided by the individual Member States, as long as there was a system to verify the data provided. Such a system has not yet been established [38,39,41]. Meanwhile, one may believe that no one would make a mistake in establishing and submitting the required data.

The European Commission noticed that, in 2012, the final year of the first reporting period, 20 Member States had achieved the 2012 target for collection rates of portable batteries, set at 25%. At the end of the second implementation report, which corresponded to the 2014 collection exercise, most EU Member States had met or exceeded the target. However, considering the number of portable batteries placed on the market and of waste batteries collected for the EU as a whole, the collection rate met the Directive's 2012 target (25%) but not the 2016 target (45%). It means that too many waste portable batteries still end up in the wrong waste stream and are lost [38,41] (see Table 1 below).

The European Commission aptly noticed the problems. The European Union was not ready to be the undisputed leader in the production, use and recycling of batteries and accumulators, which would play a key role in the industrial and agricultural production. Because of the green policy, there are initiatives at the EU level to strengthen the EU efforts in this area [38,41].

The European Commission assumes that the number of batteries placed on the EU market will sharply increase in the coming years. It could be caused by the increased global population, particularly the large and growing population living in cities. Moreover, the market for electric vehicles in the EU is growing. It is estimated that by 2025, the total battery storage capacity in the EU will be between 11,500 MW and 14,500 MW. In addition, lithium-ion batteries, in particular, are considered the primary future storage technology due to cost reductions and the rapid scale-up of manufacturing capacities [38,41]. Therefore, it is evident that there is a need to strengthen the management system of waste batteries and accumulators.

Table 1. EU and Member States collection rates in the years 2014–2016 (%).

Country	2014	2015	2016
EU	39.4	41.0	43.8
Croatia	19.0	29.3	100.2
Belgium	54.6	55.6	70.7
Luxembourg	65.0	60.2	63.4
Hungary	37.0	43.7	53.1
Lithuania	32.8	42.5	52.7
Czechia	31.5	36.3	52.0
Austria	53.8	55.1	49.2
The Netherlands	45.0	46.0	49.0
Bulgaria	45.3	44.6	48.5
Ireland	32.6	33.2	48.0
Slovakia	66.0	53.0	47.2
Germany	44.2	45.3	46.2
Finland	46.0	47.0	46.0
Sweden	59.0	61.0	45.1
Denmark	44.3	45.6	44.6
France	36.8	38.5	44.5
The UK	36.0	44.0	ND
Portugal	28.0	31.1	41.6
Poland	33.0	38.0	39.0
Spain	36.4	41.4	38.2
Slovenia	29.0	35.0	36.0
Italy	34.1	36.4	35.3
Estonia	22.2	41.9	30.6
Latvia	28.4	25.0	30.0
Cyprus	19.0	27.0	28.0
Malta	21.0	39.4	27.2
Greece	34.4	ND	ND
Romania	31.9	20.6	ND

ND—data are not available.

Poland has not achieved the required annual collection levels for portable waste batteries and spent accumulators. In 2014–2016, the collection rate was 33 percent, 38 percent and 39 percent, respectively, while the collection levels required by the Environment Minister were 35 percent, 40 percent and 45percent. The Polish SAI found that the data about collected waste portable batteries and accumulators may not be entirely reliable. The Polish SAI disclosed errors in the Chief Inspector of Environmental Protection reports, which included data from reports sent by voivodship marshals (local government administration bodies at the regional level; Poland is divided into 16 regions) [42].

Data on the quantity (weight) of collected waste portable batteries and accumulators, included in reports sent to voivodship marshals by entities placing batteries on the market or accumulators, differed significantly from the data reported by entities collecting waste batteries and accumulators. Data showed by those who collected waste batteries and accumulators were higher than data showed by entities placing batteries and accumulators on the market by over 44 percent in 2015 and over 100 percent in 2016, although they should remain at a similar level. It means that the data shown for several years in the reports were unreliable. Such a situation may indicate a shadow economy in the management of waste batteries and accumulators. In addition, those who collected waste batteries or accumulators remained practically outside the inspection of the Environmental Protection Inspectorate. The disproportions between data of the masses of collected waste portable batteries available in the Chief Inspectorate for Environmental Protection and data of collected portable waste batteries available in the reports of firms placing batteries or accumulators on the market, as well as data provided by those who collected waste batteries or accumulators, undermine the reliability of reporting existing in this area. Additionally, reports on the functioning management of batteries and accumulators and waste batteries

and accumulators for 2015 and 2016, prepared by the Chief Inspector of Environmental Protection (CIEP), were not reliable [42].

The success of any project depends, among other things, on the effective obtaining of information by interested parties. The research showed that the communes implemented the obligation (introduced by the ABA) to inform and educate the local society on how to select municipal waste. These activities mainly focused on providing information on segregating and collecting waste on the commune's websites and distributing leaflets and brochures on segregating used batteries and accumulators. A list of collection points of waste batteries or accumulators in a given region was also made available on the websites of the regional local government. However, the SAI's audits did not show the effectiveness of this information activity. In other words, what percentage of the region's inhabitants knew where and how to return waste batteries and accumulators [42].

The SAI found that the required stationary separate collection points of waste batteries and accumulators (SSCP) were not established in two of nine audited municipalities. Such points were not established in three municipalities until 2016, while the ABA obliged municipalities to establish such points from 2013. A share of these above SSCPs in the process of collecting waste batteries and accumulators was negligible. Six of nine audited local governments did not collect a single waste battery and a single used accumulator via the SSCPs [42]. This was indirect evidence of the low effectiveness of the local government's information campaign. It was not enough to post information on the municipal website. Municipalities should analyse whether the information is helpful for local society and modify information activities if necessary.

Annual reports of communes on the implementation of ABA requirements should be sources of information on the management of waste batteries and accumulators. Meanwhile, all audited communes did not have information about managing waste batteries and accumulators because it was a gap in the law. This meant the entities managing this waste (apart from SSCP operators) were not obliged to submit any reports to municipalities in this regard. Therefore, the communes did not have complete information on the weight and quantity of waste batteries and accumulators collected in their area [42]. Meanwhile, the logic of the management system of waste batteries and accumulators in the situation of various entities that are part of this system requires the gathering of aggregated data by municipalities. They could then modify their information policy to better encourage local communities to segregate waste batteries and accumulators. Sixteen Polish regional environmental protection offices (PREPO) should play an important role in the battery and accumulator management system. It was found that these public institutions carried out audits of entities obliged to apply the provisions of the ACA, but the share of such audits in the total number of audits carried out by PREPO was negligible and did not exceed 2 percent per year. PREPO audited entities placing batteries or accumulators. Entities responsible for collecting waste batteries or accumulators and authorised, among other things, for issuing certificates on the weight of collected waste portable batteries and accumulators practically were outside PREPO's audits.

Meanwhile, in this area of the battery and accumulator management system, the supervision of State institutions should be intensified due to the need to counteract fraud and trade in unreliable certificates. The reason for the inadequate supervision of PREPO was underfunding, which resulted in staff shortages. Low wages of PREPO employees could catalyse a significant staff turnover, contribute to vacancies, and, consequently, to a significant burden of audits of employees of the PREPO inspection division [42]. The heads of Polish regional local governments (Voivodship Marshals) are another critical element of the battery and accumulator management system and can audit entrepreneurs obliged to apply the ACA regulations. From 2015 to 2017 (the first half of the year), the analysed regional local governments audited such entrepreneurs to a minimal extent. At the same time, these audits did not cover entities collecting portable waste batteries or waste accumulators because the ACA regulations made it impossible for Voivodeship Marshals to obtain information on entities conducting such activities in a given region.

Therefore, it was not easy to audit entities without knowing their location [42]. This was another identified severe gap in public oversight over the management of the battery and accumulator system.

The third public institution overseeing the entities obliged to apply the ACA—Provincial Inspectorates of the Trade Inspection—correctly supervised the entities placing batteries or accumulators on the market. The issues of the battery and accumulator market were taken into account in long-term audit plans. Sanctions against ACA violators were applied correctly. It should be noted, however, that only operators selling batteries and accumulators were properly supervised. Inadequate supervision concerns entities whose activities should serve the most significant possible recovery of metals from waste batteries and accumulators and protect the environment. Therefore, it is possible to generalise that the activities of public administration institutions were not conducive to the proper management of waste batteries and accumulators [42].

Loopholes in the reporting system of entities required to apply the ACA regulations and the lack of a nationwide database on waste and entities operating on the waste market reduced the reliability of the investigated Polish management system of waste batteries and accumulators.

In particular, the reliability of reports submitted to the Marshals of Voivodeships by entities managing waste batteries and accumulators concerning the mass of collected waste batteries and accumulators and the achieved collection levels raises concerns. These data shown in the reports submitted by those placing batteries or accumulators on the market and by those who collected the waste batteries and accumulators should be consistent with each other. The data from both types of entities differed significantly, even by 100 percent. Moreover, the reports (prepared by the Chief Inspector of Environmental Protection in Warsaw) on Poland's batteries and accumulators management for 2015–2016 were not entirely reliable because of incorrect numerical data in the statements, incorrect methodology for calculating the coefficients presented in the reports and the selective use of source data [42]. For example, the annual report for 2016 showed a 26 percent lower mass of waste batteries and accumulators collected in Poland. In both reports (for 2015 and 2016), the masses of waste batteries and accumulators collected in 16 Polish regions were incorrectly shown, and the percentage of entrepreneurs who achieved the required collection level was incorrectly indicated. Doubts were raised by the data presented in annual reports and collective reports on the masses of waste batteries and accumulators treated by the waste batteries and accumulators treatment plants. The content of the reports showed, for example, that in 2015 and 2016, processing plants conducting metal recovery processes processed the mass of waste batteries and accumulators more than 2.5 times greater than the mass of all waste batteries and accumulators collected in a given year in Poland, which is impossible. Surprisingly, waste battery and accumulator treatment plants showed fluctuations in the achieved recycling levels, calculated as a percentage of the mass of waste batteries and waste accumulators subjected to treatment processes to the mass adopted to treat waste batteries and accumulators. In 2015, the level of recycling was as high as 109.68 percent, and in 2016 it fell to 67.79 percent, which in annual reports was explained by the processing of accumulated inventories of waste batteries and accumulators (in the case of 2015) and the storage of collected waste batteries and accumulator (for 2016). Such results and explanations were questionable because of the requirements of the ACA. According to ACA provisions, waste batteries and accumulators intended for processing and recycling may be stored for no longer than one year, jointly by all subsequent owners of this waste. In the annual report of the Chief Inspector of Environmental Protection for 2015, the mass of waste batteries and accumulators collected in only one region was under-estimated by 6,622.81 kg, while the annual report for 2016 underestimated the weight of used batteries and accumulators in another region by as much as 819,258.80 kg. In addition, in the 2016 annual report, the weight of waste batteries and accumulators exported abroad for processing was underestimated by 400,542 kg [42]. The Chief Inspector of Environmental Protection used the wrong reporting methodology

and assumed that those who did not submit reports within the time frame specified in the ACA regulations should be treated such as those who did not achieve the required collection levels of waste batteries and accumulators [42]. It was a mistake, because it was evident that one cannot assume the equality between the untimely performance of reporting duties and the failure to meet the obligation to collect waste batteries and accumulators. In order to improve the effectiveness of supervision over the functioning of the battery and accumulator market, the Polish SAI recommended, among other things, for the Minister of the Environment to undertake activities in the media, including social media, to enhance pro-ecological attitudes among citizens. The Polish SAI also recommended solutions to increase collection points for portable waste batteries and accumulators, particularly close to households. Moreover, the Polish SAI pointed out the necessity of strengthening the human resource of the Environmental Protection Inspections [42].The analysis of webpages of other SAIs from the EU Member States showed that these SAIs did not evaluate data reliability on the level of collected waste portable batteries and accumulators such as in the case of the Polish SAI. They also did not review their domestic oversight systems on the management of batteries and accumulators [43–68]. We believe that, in cases of unreliable reporting in one EU country—Poland—, there is no 100 percent certainty that such a situation did not occur in other EU countries. Meanwhile, reliable data are the basis for developing correct decisions in managing any resources. [69].

4. Conclusions

Usually, energy is associated with the energy industry, nuclear power plants, coal or lignite mines, wind turbines or solar panels. Meanwhile, batteries and accumulators also play a massive role in the energy supply system, and the growing market of electric cars confirms this statement. The importance of the problem was demonstrated by the numerous initiatives of the European Union aimed at the better recycling of batteries and accumulators and to develop an innovative, competitive and sustainable battery value chain in Europe. Interestingly, little is known about the management system of waste batteries and accumulators and the recovery of rare earth metals. This research was concerned about how the Member States of the European Union have implemented the provisions of Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC (*Journal of Laws* EU.L.2006.266.1 of 2006.09.26).

The effective functioning of the battery and accumulator management system requires, firstly, the correct implementation of the provisions of EU law into national laws; then, the creation of a supervision system for placing batteries and accumulators on the markets and, then, the recovery and use of waste batteries and accumulators, as well as reliable reporting on activities. We believe that the Polish regional environmental protection offices should audit entities obliged to implement the Polish Act on batteries and accumulators. Moreover, supreme audit institutions should play a significant role in such a system, which, due to their positions in macrostructures—the States—could comprehensively examine and evaluate whether the management system of waste batteries and accumulators is correct. It provides the basis for reliable reporting. In the case of Poland, the supreme audit institution evaluated the domestic management system of batteries and accumulators. It showed that the public administration institutions were not ready to create a fully coherent and effective oversight system on managing batteries and accumulators. The reporting system was flawed. It might limit the reliability of the European Union reporting, which is the basis of the European energy policy. We believe that the Polish SAI should expand its audit scope and evaluate whether the informative activities to create positive attitudes toward recycling rare metals and protecting the environment are efficient.

Based on this study, we can formulate conclusions expanding the Polish case. The European Battery Alliance and the European Commission strategic action plan for batteries adopted in 2018 setting out a comprehensive framework of regulatory and non-regulatory measures to support all segments of the battery value chain require two basic needs and

crucial components. First, reliable reporting. Second, a comprehensive system of the evaluation of management waste batteries and accumulation in each European Union Member State. We found unreliable data sent by the Polish authorities to the European Commission. The research also showed that only the Polish supreme audit institution verified the management system of waste batteries and accumulators. It may raise questions whether all the EU Member States reliably fulfilled report requirements and adequately executed the Battery Directive.

The following avenues for further research may emerge from the present study. Firstly, the present study was based on a review of published studies in Poland. This was a limitation of our study. An interesting topic for further studies might be to conduct a study to conclude how reliable were the reports sent to the European Commission by other countries and the generalisability with statistical reliability. Secondly, practitioners' readiness to understand and adopt theories in their daily businesses requires practical tools. While many practitioners have realised the importance of research, the communication gap between academics and practitioners still exists. Therefore, there is a need to develop an e-reporting system for managing waste batteries and accumulators with an adequate validation system. In addition, more research is required to determine why other SAIs did not review and evaluate the management of their domestic system of waste batteries and accumulators. It would be interesting to study the influence of framing on the recycling system in particular countries. We believe that any directives and regulations should be accompanied by creating appropriate informal institutions according to the logic of the New Institutional Economy. This study can form a source for an inquiry process in any country; thus, contributing to a better contextual diagnosis of the stage where the States improve their recycling systems.

Author Contributions: Conceptualization: Z.D. and Ł.S.; Funding acquisition: Z.D.; Investigation; Z.D. and Ł.S.; Methodology: Z.D. and Ł.S.; Project administration: Z.D.; Resources: Z.D. and Ł.S.; Supervision: Z.D. and Ł.S.; Validation: Z.D. and Ł.S.; Visualization: Z.D. and Ł.S.; Writing—original draft: Z.D. and Ł.S.; Writing—E review and editing: Z.D., Ł.S. and W.D. All authors have read and agreed to the published version of the manuscript.

Funding: The open access license of the publication was funded by the Priority Research Area Society of the Future under the program "Excellence Initiative—Research University" at the Jagiellonian University in Kraków.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

References

1. Thollander, P.; Ottosson, M. Energy management practices in Swedish energy-intensive industries. *J. Clean. Prod.* **2010**, *18*, 1125–1133. [CrossRef]
2. Thollander, P.; Ottosson, M. An energy efficient Swedish pulp and paper industry—exploring barriers to and driving forces for cost-effective energy efficiency investments. *Energy Effic.* **2008**, *1*, 21–34. [CrossRef]
3. Lee, D.; Cheng, C.-C. Energy savings by energy management systems: A review. *Renew. Sustain. Energy Rev.* **2016**, *56*, 760–777. [CrossRef]
4. Olatomiwa, L.; Mekhilef, S.; Ismail, M.S.; Moghavvemi, M. Energy management strategies in hybrid renewable energy systems: A review. *Renew. Sustain. Energy Rev.* **2016**, *62*, 821–835. [CrossRef]
5. Tie, S.F.; Tan, C.W. A review of energy sources and energy management system in electric vehicles. *Renew. Sustain. Energy Rev.* **2013**, *20*, 82–102. [CrossRef]
6. Liu, Y.; Yang, C.; Jiang, L.; Xie, S.; Zhang, Y. Intelligent Edge Computing for IoT-Based Energy Management in Smart Cities. *IEEE Netw.* **2019**, *33*, 111–117. [CrossRef]
7. Zhang, F.; Hu, X.; Langari, R.; Cao, D. Energy management strategies of connected HEVs and PHEVs: Recent progress and outlook. *Prog. Energy Combust. Sci.* **2019**, *73*, 235–256. [CrossRef]

8. Hua, H.; Qin, Y.; Hao, C.; Cao, J. Optimal energy management strategies for energy Internet via deep reinforcement learning approach. *Appl. Energy* **2019**, *239*, 598–609. [CrossRef]
9. Rohdin, P.; Thollander, P.; Solding, P. Barriers to and drivers for energy efficiency in the Swedish foundry industry. *Energy Policy* **2007**, *35*, 672–677. [CrossRef]
10. Greenbaum, P.J. Spending money elsewhere. *Pulp Pap. Can.* **2001**, *102*, 11–14.
11. European Commission. Internal Market, Industry, Entrepreneurship and SMEs. European Battery Alliance. Available online: https://ec.europa.eu/growth/industry/policy/european-battery-alliance_en (accessed on 14 August 2021).
12. Shabani, B.; Biju, M. Theoretical Modelling Methods for Thermal Management of Batteries. *Energies* **2015**, *8*, 10153–10177. [CrossRef]
13. He, H.; Xiong, R.; Guo, H.; Li, S. Comparison study on the battery models used for the energy management of batteries in electric vehicles. *Energy Convers. Manag.* **2012**, *64*, 113–121. [CrossRef]
14. Dufo-López, R.; Bernal-Agustín, J.L.; Domínguez-Navarro, J.A. Generation management using batteries in wind farms: Economical and technical analysis for Spain. *Energy Policy* **2009**, *37*, 126–139. [CrossRef]
15. Kim, G.-H.; Gonder, J.; Lustbader, J.; Pesaran, A. Thermal Management of Batteries in Advanced Vehicles Using Phase-Change Materials. *World Electr. Veh. J.* **2008**, *2*, 134–147. [CrossRef]
16. Aziz, M.; Oda, T.; Kashiwagi, T. Extended Utilization of Electric Vehicles and their Re-used Batteries to Support the Building Energy Management System. *Energy Procedia* **2015**, *75*, 1938–1943. [CrossRef]
17. Winslow, K.M.; Laux, S.J.; Townsend, T.G. A review on the growing concern and potential management strategies of waste lithium-ion batteries. *Resour. Conserv. Recycl.* **2018**, *129*, 263–277. [CrossRef]
18. Choi, Y.; Rhee, S.-W. Current status and perspectives on recycling of end-of-life battery of electric vehicle in Korea (Republic of). *Waste Manag.* **2020**, *106*, 261–270. [CrossRef] [PubMed]
19. Singh, S.; Weeber, M.; Birke, K.P.; Sauer, A. Development and Utilization of a Framework for Data-Driven Life Cycle Management of Battery Cells. *Procedia Manuf.* **2020**, *43*, 431–438. [CrossRef]
20. Malinauskaite, J.; Jouhara, H.; Czajczyńska, D.; Stanchev, P.; Katsou, E.; Rostkowski, P.; Thorne, R.J.; Colón, J.; Ponsá, S.; Al-Mansour, F.; et al. Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. *Energy* **2017**, *141*, 2013–2044. [CrossRef]
21. Thomann, E.; Sager, F. Moving beyond legal compliance: Innovative approaches to EU multilevel implementation. *J. Eur. Public Policy* **2017**, *24*, 1253–1268. [CrossRef]
22. Zhelyazkova, A.; Thomann, E. 'I did it my way': Customisation and practical compliance with EU policies. *J. Eur. Public Policy* **2021**, *17*, 1–21. [CrossRef]
23. Börzel, T.A.; Buzogány, A. Compliance with EU environmental law. The iceberg is melting. *Environ. Politics* **2019**, *28*, 315–341. [CrossRef]
24. Brzeszczak, A. System for the management of waste batteries and accumulators in Poland. *World Sci. News* **2019**, *127*, 272–283.
25. Rogulski, Z.; Czerwiński, A. Used batteries collection and recycling in Poland. *J. Power Sources* **2006**, *159*, 454–458. [CrossRef]
26. Sułkowski, Ł. Teorie, paradygmaty, metafory i ideologie zarządzania—kontrowersje wokół współczesnego dyskursu organizacji i zarządzania [Theories, paradigms, metaphors and ideologies of management—different ways of performing organizational and managerial discourse. Scientific Papers of the University of Economics in Wrocław]. *Pr. Nauk. Uniw. Ekon. We Wrocławiu* **2016**, *422*, 131–143.
27. Sułkowski, Ł. *Epistemologia i Metodologia Zarządzania*; Polskie Wydawnictwo Ekonomiczne: Warszawa, Poland, 2012.
28. Urbański, M. *Rozumowania Abdukcyjne. Modele i Procedury*; Wydawnictwo Naukowe Uniwersytetu Adama Mickiewicza: Poznań, Poland, 2010.
29. Eckstein, H. Case Study and Theory in Political Science. In *Case Study Method. Key Issues. Key Texts*; Gom, R., Hammersley, M., Foster, P., Eds.; Sage Publications: London, UK; Thousand Oaks, CA, USA; New Delhi, India, 2000; pp. 119–164.
30. Nordqvist, M.; Gartner, W.B. Literature, fiction, and the family business. *Fam. Bus. Rev.* **2020**, *33*, 122–129. [CrossRef]
31. Short, J.C.; Payne, G.T. In Their Own Words: A Call for Increased Use of Organizational Narratives in Family Business Research. *Fam. Bus. Rev.* **2020**, *33*, 342–350. [CrossRef]
32. Treib, O. Implementing and complying with EU governance outputs. *Living Rev. Eur. Gov.* **2008**, *3*, 1–30. [CrossRef]
33. National Audit Office. *State Audit in the European Union*; NAO: London, UK, 2005.
34. Dobrowolski, Z. The supreme audit institutions readiness to uncertainty. *Entrep. Sustain. Issues* **2020**, *8*, 513–525. [CrossRef]
35. Sułkowski, Ł.; Dobrowolski, Z. The role of supreme audit institutions in energy accountability in EU countries. *Energy Policy* **2021**, *156*, 112413. [CrossRef]
36. Dobrowolski, Z. Energy and Local Safety: How the Administration Limits Energy Security. *Energies* **2021**, *14*, 4841. [CrossRef]
37. The European Commission. SWD (2019) 1300 Final. Commission Staff Working Document on the Evaluation of the Directive 2006/66/EC on Batteries and Accumulators and Waste Batteries and Accumulators and Repealing Directive 91/157/EEC. Brussels. 9 April 2019. Available online: https://ec.europa.eu/environment/pdf/waste/batteries/evaluation_report_batteries_directive.pdf (accessed on 11 May 2021).
38. European Commission. Batteries and Accumulators. Available online: https://ec.europa.eu/environment/topics/waste-and-recycling/batteries-and-accumulators_en (accessed on 11 May 2021).

39. European Commission. COM (2018) 293 Final. ANNEX 2 to the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Europe on the Move. Sustainable Mobility for Europe: Safe, Connected and Clean Brussels. 17 May 2018. Available online: https://eur-lex.europa.eu/resource.html?uri=cellar:0e8b694e-59b5-11e8-ab41-01aa75ed71a1.0003.02/DOC_3&format=PDF (accessed on 14 August 2021).
40. European Commission. COM (2019) 166 Final. Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Implementation and the Impact on the Environment and the Functioning of the Internal Market of Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on Batteries and Accumulators and Waste Batteries and Accumulators and Repealing Directive 91/157/EEC. Brussels. 9 April 2019. Available online: https://ec.europa.eu/environment/pdf/waste/batteries/report_implementation_batteries_directive.pdf (accessed on 12 May 2021).
41. Najwyższa Izba Kontroli. System Gospodarowania Zużytymi Bateriami i Akumulatorami. Nr Ewidencyjny: P/17/109. Warszawa. 2018. Available online: https://www.nik.gov.pl/kontrole/P/17/109/ (accessed on 11 May 2021).
42. Rechnungshof. Available online: https://www.rechnungshof.gv.at/rh/suche/search.html?l=en&q=batteries+and+accumulators&thema=&Bereich= (accessed on 16 May 2021).
43. Court of Audit. Belgium. Available online: https://www.ccrek.be/EN/Search.html (accessed on 16 May 2021).
44. Czech Republik. Supreme Audit Office. Available online: https://www.nku.cz/scripts/rka-en/prehled-kontrol.asp?nazevakce=Batteries+and+accumulators&casovyfiltr=0&kategorie=0&rozsirene=1&odeslano=1 (accessed on 16 May 2021).
45. Republic of Croatia. State Audit Office. Available online: https://www.revizija.hr/search-results/771?q=batteries+and+accumulators (accessed on 16 May 2021).
46. Bulgarian National Audit Office. Available online: https://www.bulnao.government.bg/en/search?q=batteries+and+accumulators&article_id=&child_article_id=&file_category_id=&file_type_id=&date_from=&date_to= (accessed on 16 May 2021).
47. Rigsrevisionen. Available online: https://uk.rigsrevisionen.dk/search-results?query=batteries (accessed on 16 May 2021).
48. Riigikontrolli. Available online: https://www.riigikontroll.ee/Riigikontrollipublikatsioonid/tabid/103/language/en-US/Default.aspx (accessed on 16 May 2021).
49. National Audit Office of Finland. Available online: https://www.vtv.fi/en/?vs_q=batteries+and+cc (accessed on 16 May 2021).
50. Cour des Comptes. Available online: https://www.ccomptes.fr/en (accessed on 16 May 2021).
51. Bundesrechungshof. Available online: https://www.bundesrechnungshof.de/en/@@search?SearchableText=batter+ (accessed on 16 May 2021).
52. Hellenic Court of Audit. Available online: https://www.elsyn.gr/en/node/1166 (accessed on 16 May 2021).
53. Hungarian Supreme Audit Office. Available online: https://www.asz.hu/en/search (accessed on 16 May 2021).
54. Office of the Comptroller and Auditor General. Ireland. Available online: https://www.audit.gov.ie/en/search/?q=batteries+and+accumulators (accessed on 16 May 2021).
55. Corte Dei Conti. Available online: https://www.corteconti.it/Home/EnglishCorner (accessed on 16 May 2021).
56. Latvian Supreme Audit Office. Available online: https://www.lrvk.gov.lv/en (accessed on 16 May 2021).
57. Lithuanian Supreme Audit Office. Available online: https://www.vkontrole.lt/audito_ataskaitos_en.aspx?tipas=15 (accessed on 16 May 2021).
58. Luxembourg. Cour Des Comptes. Available online: https://cour-des-comptes.public.lu/fr/support/recherche.html?q=batteries+ (accessed on 15 May 2021).
59. National Audit Office. Malta. Available online: https://nao.gov.mt/en/search (accessed on 15 May 2021).
60. Audit Office. Republic of Cyprus. Available online: http://www.audit.gov.cy/audit/audit.nsf/AdvancedSearch_en/AdvancedSearch_en?OpenForm&q=&p=1&w=&t=&s=batteries%20and%20accumulators&L=E&e=&i=1 (accessed on 16 May 2021).
61. Algemene Rekenkamer. Available online: https://www.rekenkamer.nl/zoeken?trefwoord=batteries+and+accumulators&search-submit= (accessed on 16 May 2021).
62. Tribulan De Contas. Available online: https://www.tcontas.pt/pt-pt/MenuSecundario/Pesquisa/Pages/resultadospesquisa.aspx?k=batteries%20and%20accumulators (accessed on 16 May 2021).
63. Romanian Court of Accounts. Available online: http://www.rcc.ro/Publicatii.aspx?niv1=5/12/2014%202:57:40%20PM (accessed on 16 May 2021).
64. Slovakia. National Audit Office. Available online: https://www.nku.gov.sk/sk/home?p_p_id=3&p_p_lifecycle=0&p_p_state=maximized&p_p_mode=view&_3_struts_action=%2Fsearch%2Fsearch&_3_redirect=%2F&_3_keywords=baterie+i+akumulatory (accessed on 16 May 2021).
65. Republic of Slovenia. Court of Audit. Available online: https://www.rs-rs.si/en/search/?tx_indexedsearch_pi2%5Baction%5D=search&tx_indexedsearch_pi2%5Bcontroller%5D=Search&cHash=3c213a949f187fcac121838de41d1374 (accessed on 16 May 2021).
66. Tribunal De Cuentas. Available online: https://www.tcu.es/tribunal-de-cuentas/en/search/summary/index.html?text=batteries%20and%20accumulators (accessed on 16 May 2021).
67. Swedish National Audit Office. Available online: https://www.riksrevisionen.se/en/search.html?submitButton=&query=batteries+and+accumulators#query/batteries%20and%20accumulators (accessed on 16 May 2021).
68. Robbins, S.P.; Coulter, M.; Decenzo, D.A. *Fundamentals of Management*, 11th ed.; Pearson: New York, NY, USA, 2020; pp. 1–526.
69. Dobrowolski, Z. Internet of Things and Other E-Solutions in Supply Chain Management May Generate Threats in the Energy Sector—The Quest for Preventive Measures. *Energies* **2021**, *14*, 5381. [CrossRef]