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Review

Circular Economy Approaches for Electrical and Conventional Vehicles

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Abstract: The purpose of this article is to analyze the current state of the research and the trends in the field of Circular Economy (CE) for the automotive industry, with electric vehicles (EVs) and conventional vehicles (CVs), being analyzed separately. A systematic literature search was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method, to screen and select articles from the Clarivate Web of Science database. For the detailed analysis, the information from the selected articles was structured based on such criteria as study objective, findings, limitations, and research proposals, and was further organized into nine categories for EVs, and into four categories for CVs. There were several CE strategies identified in the review, but a major challenge remains the evaluation of these strategies, in order to determine the most relevant, effective, and efficient ones, starting from the goal of minimizing the resource functionality loss. Future studies should focus on promoting new green technologies in the automotive industry, with an emphasis on circularity, in terms of raw materials, energy, production systems, product life extension, second use application, reuse, recycling, and end of life.

Keywords: circular economy; automotive industry; electrical vehicle; conventional vehicle; environmental impact

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1. Introduction

In a world with limited resources, sustainability has become a key concept in carrying out any type of activity [1]. In addition to the diversity of products and services, the consumer market, which has grown rapidly in recent years, also has negative effects. Unfortunately, excessive consumption of natural resources and the resulting waste therefrom, destabilize the environment, and harsh practices are needed to control these negative effects.

At present, the industry operates based on a linear model, in which products are created from natural resources that have been transformed into products that are used for a certain period, then either recycled or put into landfills. A transition is necessary from a linear model of the "take-make-dispose" type, to a circular one, focused on the reduction of raw material consumption and on waste management, by reducing waste disposal [2,3].

The circular economy (CE) has grown in recent years and, "represents an environmentally and sustainability-focused economic paradigm" [4]. The concept of CE has been used since 1966, when Boulding recommended that ecological systems must be cyclical in order to support constant production [5]. Later, in the 1990s, the idea was supported by the environmental economists Pearce and Turner, when analyzing the flow of materials in which resources could be reused or recycled so that they could be used for other purposes [5].

CE is "an economic system that is based on business models which replace the 'end-of-life' (EoL) concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. The impact of the CE could be at micro level (products, companies, consumers), meso-level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to create environmental quality, economic prosperity and social equity, to the benefit of current and future generations" [6].

CE is a "regenerative system, designed to reduce waste and aim at guaranteeing the eco-sustainability of post use products" [7], and "...in which resource input and waste, emission, and energy leakage are minimized by slowing, closing and narrowing material and energy loops" [8]. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling [8,9].

The transition to a CE, according to the European Commission, focuses on "integrating life cycle thinking in product design and all subsequent life cycle stages in order to enable efficient recycling, recovery, repair and re-use" [10]. For an efficient CE, systemic adaptations are needed for the greatest possible preservation of the functionality of products (extension of lifetime), components (reuse), and materials (recycling), with energy saving and sustainable materials [11,12].

The transport sector is among the main sectors responsible for global warming, accounting for one-third of energy demand and one-sixth of global greenhouse gas emissions [13,14].The challenges in the automotive industry are numerous and of different types. On the one hand, they are influenced by the needs of the market, and the adaptation to the requirements of the final consumers and, on the other hand, by compliance with legislative requirements at the national, regional, or even global level.

The automotive industry, through its specific activities, number and diversity of components and resources used, and even through its very large size and structure, has a significant impact on the environment at each stage of the life cycle: raw materials, production, use stage, and end-of-life [15,16]. The manufacture of vehicles has an impact on the environment because the process consumes large amounts of water, natural resources, and energy, and has a negative impact on carbon emissions. Moreover, in the EoL stage, the waste ends up either incinerated or in landfills, and has an impact on air acidification and water eutrophication [5].

Depending on the energy used, vehicles can be classified as conventional (using tradition combustion engines), or electric, which category can be further subdivided into battery electric vehicle (BEV), hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV), extended-range electric vehicle (EREV), and fuel cell vehicle (FCV) [17].

Previous studies showed that EVs have a low fuel consumption and also low CO_2 emissions [18]. On the other hand, given the weight and chemical composition of the electric battery, it is important to analyze how this new generation of vehicles affect the environment, especially in the EoL stage [19]. Other concerns include the availability and extraction of the rare materials, especially lithium, used in the manufacturing of the batteries [20,21]. Some authors consider that electromobility based on LIBs is a bridging technology, until LIBs are replaced by green hydrogen fuel cells [20].

The appearance of EVs is relatively new, and the automotive industry is on an upward trajectory in the manufacture and sale of EVs. This is why it is necessary to investigate how EVs influence this transformation of the automotive industry, including environmental protection issues and CE. On the other hand, conventional vehicles (CVs) still represent a large proportion of the automotive industry, which is why a holistic approach to the automotive industry, including both categories of vehicles in terms of CE, is needed.

Considering these aspects, the authors considered that the correct approach to this study was to determine the short- and medium-term impacts of EVs and CVs on the environment, following CE principles and models.

The main purpose of this paper is to identify and discuss CE strategies for the automotive industry, and to indicate how such strategies should be evaluated in order to determine the most relevant, effective, and efficient ones, presuming a goal of minimizing resource functionality loss.

Another focus will be on new green technologies in the automotive industry, with an emphasis on circularity in terms of raw materials, energy, production systems, product life extension, second use application, reuse, recycling, and EoL.

A special section will be dedicated to the environmental impact of batteries for the EVs, secondary users, and the recycling stage, including strategies for battery recycling and improvement solutions.

The paper is organized as follows: the methods used in this paper are explained in Section 2; a detailed literature review is presented in Section 3; followed in Section 4 by an analysis of relevant key terms and the relationships between them; and finally, the Section 5, where we summarize the main findings and suggest future research steps.

2. Materials and Methods

Two separate bibliometric analyses were performed, in order to display the existing studies and approaches of electric and conventional vehicles in relation to CE.

A search strategy was defined, together with eligibility criteria, and a systematic review was performed based on the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) checklist. The results were further processed with the VOSViewer software for the network and hierarchical clustering analysis. The bibliographic data were collected from the Web of Science Core Collection and processed on October 2022, and updated on January 2023.

For the detailed analysis, only the publications of type Article and Reviews, published in English, were maintained.

2.1. EVs and CE–Bibliometric Analysis

The searches were performed based on the following keywords strings:

"electric vehicle*" and "environment* protection" and "sustain* develop*", with a total number of 35 articles and reviews;

"electric vehicle*" and "environment* impact" and "sustain* develop*", with a total number of 362 articles and reviews;

"electric vehicle*" and "circular economy", with a total number of 177 articles and reviews.

Of the resulting 574 publications in the initial search, 21 were eliminated as duplicates. The title and abstract screening removed another 305 studies that were considered unrelated to our research, such as studies that do not target EVs (for example, some focused on electric bicycles, electric rickshaws, smart homes, even clothes). The 248 remaining studies were analyzed in detail, focusing more on aim, findings, limitations, and further direction, in order to identify those studies that were relevant for our research. Given the size of the automotive industry, the importance of conducting an evaluation while taking into account the entire life cycle of the product, as well as the rich diversity of components that comprise the final product, we considered as eligible all articles and reviews that are part of the life cycle range of the electric vehicle, and which were approached from the perspective of environmental impact. Upon completion of this step, the number of articles considered for the detailed review was 85.

When the 85 articles were reviewed, 7 further relevant titles (based on the established criteria) were identified in their reference lists, and included in our study. This makes a total of 92 articles, each of which was retained for the detailed review.

The selection process is represented schematically in Figure 1, and the results are discussed in Appendix A.

2.2. Conventional Vehicles and CE–Bibliometric Analysis

The search query in this case was defined based on the keywords: "vehicle" and "circular economy".

Based on the PRISMA approach, and using the same algorithm as presented before, (Figure 2), we selected 33 articles for the detailed review (please see also Appendix B).

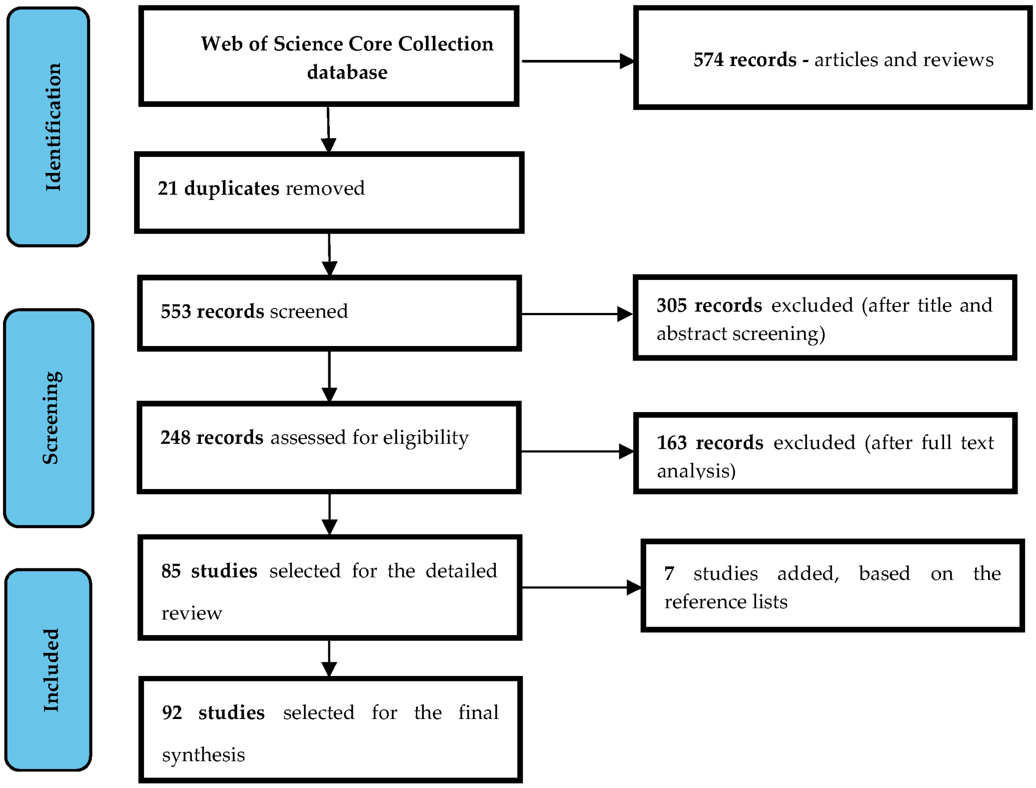


Figure 1. PRISMA flow diagram for the bibliometric analysis of the CE approaches for EVs.

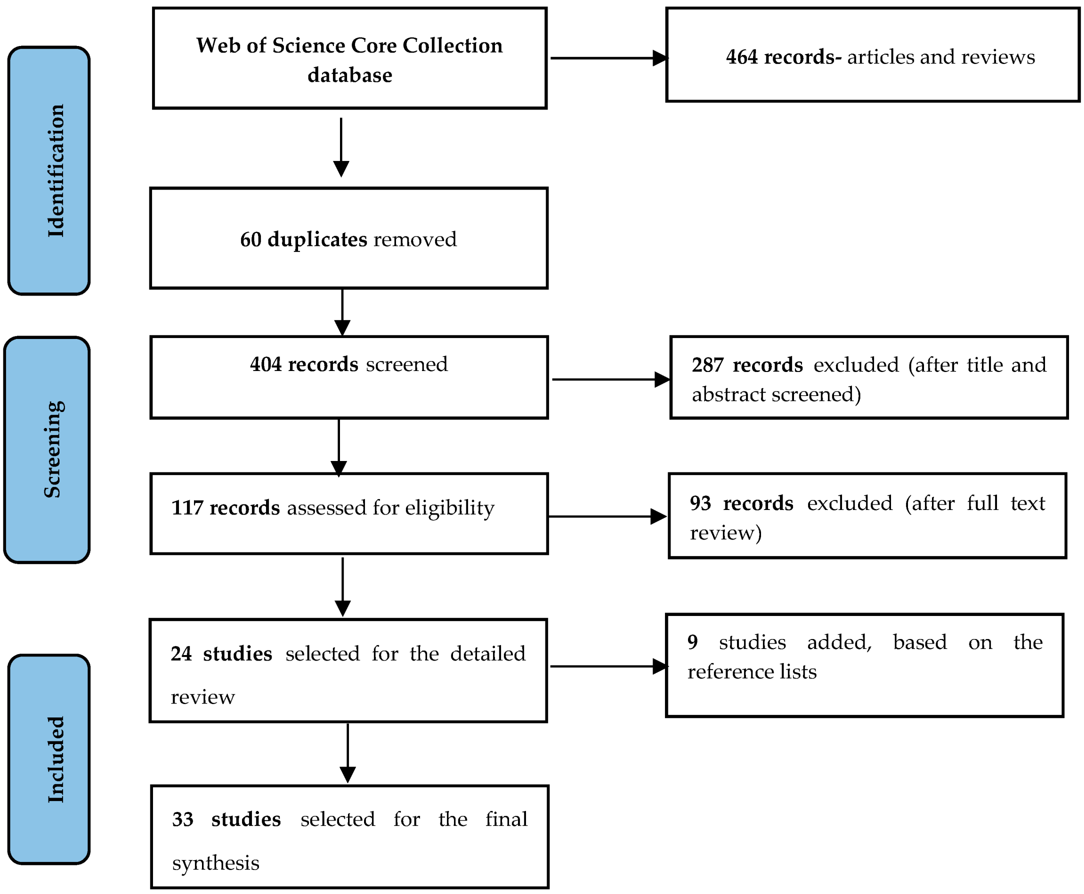


Figure 2. PRISMA flow diagram for the bibliometric analysis of the CE approaches for CVs.

3. Literature Review

The circular business models, in addition to the sustainable value involved, also play the role of "close, slow and narrow resource loops" [5,6]. Although sustainable business has grown in the last years, new types of business models are needed, together with practical tools for a CE [22]. There are also gaps in the specialized literature regarding CE indicators, especially at the micro level (operationalization of the organization level). Such developments would be beneficial to a much clearer understanding of the concept [23].

Raising awareness of the CE concept and its benefits, as well as the bottlenecks in its implementation, is the cornerstone of the adoption of CE strategies [5,24]. Research is still considered insufficient, as only a few studies that aim to integrate the principles of the CE into business practices, have been identified [23]. To fill the gaps, the development of survey studies is recommended, allowing companies and consumers to highlight their level of awareness, in order to implement the objectives of the concept [23].

Regarding the future of the automotive industry, the CE is discussed in various studies, with the main focus being on the BEVs. Unfortunately, we could not identify any studies focusing on models or tools for evaluating the CE. Most studies speak in a conceptual way of closing the loop, of diminishing the impact on the environment during the stage of extraction of raw material and battery production, but it is necessary to identify models for evaluating organizations, and even products, from the CE point of view. In our opinion, such evaluations could offer a clearer image regarding the positioning of the business in relation to CE, while at the same time offering the premise of a development in accordance with the fundamental objectives of this concept.

The next section will summarize the review of the selected articles, with the research and trends in the field of CE for EVs and CVs being presented separately.

3.1. The Electrical Vehicle and Circular Economy

In order to highlight the results and research directions, the studies described in Appendix A were grouped into nine categories, depending on the theme addressed in each article: battery management, vehicle management, life cycle sustainable assessment, transport management, consumer behavior, electricity renewable sources and charging infrastructure, raw materials, air pollution reduction strategies, and eco-design (technical design changes).

Out of the total of 92 studies, 36 studies (39%) addressed the issue of electric batteries, the approaches being focused on recycling strategies, EoL management, waste management, and second life of used batteries. The category vehicle management, includes 17 studies (18%), where topics such as the development of transport strategies and policies, energy and environment, recycling processes, and waste management, were addressed. The life cycle sustainable assessment category also includes 17 articles (18% of the total), with the main conclusion of these studies being that further developments regarding LCA are necessary for the improvement of LIBs (Lithium-Ion Battery) and EVs, and also for transport policies and for capturing the dynamics of the system. The other categories identified represent smaller numbers of articles (maximum 4 for each category).

The recommendations that resulted from the critical analysis of these articles are addressed to both research groups, and to the government organizations that are responsible for establishing and implementing strategies and policies, as summarized below, structured on the nine categories discussed in Appendix A.

A. Battery management:
   - Battery waste management—a more realistic assessment of the environmental impact of the LIBs. Develop battery reusing applications, reduce the dependence on non-renewable resources [25–29].
   - Battery recycling management—improve pollution strategy and develop regional policies to improve the recycling industry for LIBs [7,30–37].
   - Second life of used batteries—develop new business models for battery second use, involving all actors along the battery value chain. Further studies focused

on charge/discharge efficiency, battery capacity degradation, and battery lifetime [38–41].

- Battery strategies—develop policies, investments, and incentives, including "circular thinking". Intensify research for adding valuable knowledge about the LIB chain, the impact of technologies, the effects of flows, the substitution of materials, and energy transition [29,42–48].
- Environmental assessment—identify environmental consequences for the redesign, reuse, and recycle processes for rechargeable batteries. further studies that include energy consumption during the production and use phase, to determine the environmental footprint, are needed [49–53].
- Battery manufacturing—identify environmental impact and adapt the manufacturing processes for cell chemistry and compounds [29,54,55].

B. Vehicle management:

- Policies based on interaction between sustainability and EV system. Circular economy strategies to be adopted at both government and corporate levels [56–62].
- Implement government incentives to reduce environmental impact.
- Public awareness to increase environmental protection.
- Better relationship between consumers and car manufacturers [63].
- Digital twin technologies for smart EVs [64].
- Vehicle recycling process analysis [65,66].
- Sustainability optimization framework to supply chain for the automotive industry [67].

C. Life cycle sustainable assessment:

- Models for environmental effects assessment (e.g., waste collection, and strategy options like mobility on-demand or autonomous driving) and system dynamic perspective evaluation [68,69], assessment of life cycle sustainability [70], design stage [71], and dynamic LCA framework for EVs [72].
- Evaluation of the environmental, social, and economic impact [73,74].
- Cost-efficient recycling technologies [75].
- Improve manufacturing efficiency and electrochemical and environmental performance of LIBs [76,77].
- Environmental benefits of EVs compared to CVs [78].
- Identify the most used CE strategies [79].

D. Transport management:

- New worldwide transportation policies and incentives [80–82].
- Create a model for green public procurement [83] and develop charging strategies [84].

E. Consumer behavior:

- Future studies to analyze consumer preferences, following incentives for new car purchases and identifying target groups interested in purchasing sustainable cars [4,85].
- Identify factors affecting consumer purchase behavior when buying EVs [86,87].

F. Electricity renewable sources and charging infrastructure:

- Develop ecologically friendly forms of electricity generation and increase the effectiveness of electricity transmission [88].
- Develop policies considering charger quantities and life cycle cost estimation—considering other feedstock sources for hydrogen production and electricity [89,90].

G. Raw materials:

- Develop a model for evaluating the availability of strategic materials (for example non-ferrous and rare-earth metals) for supporting the decision-making

process on the raw materials market, and improve the supply sources for critical raw materials [91,92].
- Create collection programs and improve metal recovery/recycling opportunities for LIBs [93].
- Material flow analysis [94].

H. Air pollution reduction strategies:
- New policies extended to different areas in order to increase sales of EVs, increase percentage of renewable energy in the electricity mix, and prevent air pollution caused by battery manufacturing [95].
- Strategies to reduce carbon emissions [96].

I. Eco-design (Technical design changes):
- Improve environmental emissions through experiments, and develop a product configurator by considering component modification for cars, in order to increase environment protections [97,98].

3.2. The Conventional Vehicle and Circular Economy

The selected studies approaching CVs (Appendix B) were classified into the following categories: CE strategies, recycling management, raw materials, and EoL management. The highest percentage is attributed to the CE strategies category, at 47%.

Actions to be taken and future research directions for each of these categories are presented below.

A. CE strategies:
- Develop strategies from a holistic life cycle approach, particularly through more scrap utilization, higher intensity of vehicle uses, and design for reuse/remanufacturing [12].
- Include circularity indicators in product evaluation [6], consider maximal potential recycling of EV steel [99].
- Complete update of strategies such as raw material recycling, resource reconstruction, extending product life, product services, and transformation from ownership to sharing [100].
- Evaluate and discover the correlation in terms of a freight transport system [101].
- Identify the parameters used for material efficiency potential [102].

B. Recycling management:
- Identify how the trade of metal scraps affects recycling and efficiency pathways [103–105].
- Further studies to assess the contribution of integrated waste management to CE [106].

C. Raw materials:
- Studies for different products, components, and materials for reuse (non-destructive) and recycle (destructive) strategies [107].
- Policies and regulations are needed to change business models and consumer behavior in order to implement product longevity strategies [8].
- Model to quantify sustainability indicators using the LCSA (Life Cycle Sustainability Assessment), multi-criteria decision- making, [108] and multi-regional input-output based LCSA framework model [109], are needed.
- Evaluation of the metals in the vehicle, including downcycling [110].

D. EOL management:
- Develop components that can be remanufactured or repaired, and collect sorted components for dedicated and functional recycling [111].

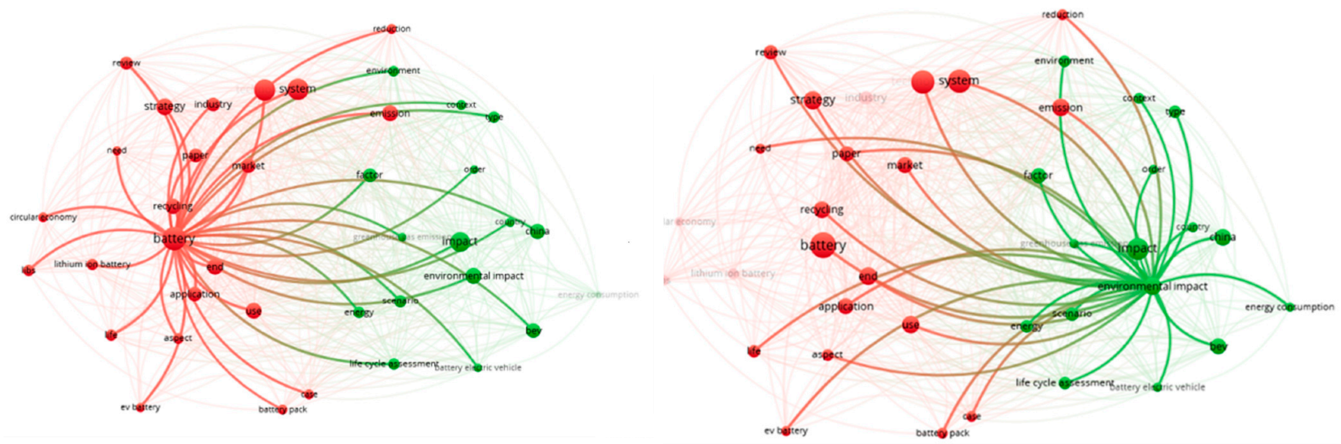
- Intensify further case studies for specific cities or companies in the automotive industry, as well as waste chain research to stimulate a higher recycling process [112].
- Better solutions and support tools for EoL, material waste reductions, recyclability of materials, and innovative forming processes for recycling [113].
- EoL alternative(s) for the used heavy vehicles collected and the components recovered after dismantling operations [114].
- Recyclability and recoverability at the EoL of the material used [115].
- Identify and apply improvement in the EoL management of heavy vehicles, from the dismantling to the economic recovery [114].

4. Results and Discussions

For the network and hierarchical clustering analysis, the studies selected for reviews were further processed using the VOSViewer software. The results are presented below.

4.1. Electric Vehicle and CE: The VOSViewer Representation

Two main clusters: “battery” and “impact”, can be observed in the VOSViewer bibliometric mapping (Figure 3), with labels and circles representing the most frequently used keywords, with the size of the label and the size of the circle being proportional to the number of occurrences for each keyword. The color of an item is determined by the group to which the item belongs. Lines between articles represent links. A link appears between two circles if the keywords associated with them appeared together more than a predetermined number of times. The keyword “electric vehicle” was deselected in order to highlight more clearly the link between the terms.



(**a**) (**b**)

Figure 3. VOSViewer network visualization—CE approaches for EVs (minimum number of co-occurrences—10 and maximum number of terms—40). (**a**) “Battery” network visualization cluster. (**b**) “Environmental impact” network visualization cluster.

A close link can be observed in the red cluster, (a), between “battery” and “recycling”, and between “end” and “circular economy”, which indicates a focus on approaches for recycling the batteries for electric vehicle (BEVs), and on models of CE. For the green cluster, (b), there is a close connection between “impact” and “environmental impact”. Moreover, “environmental impact” is closely related to “life cycle assessment”, “BEV”, and “energy consumption”. In our interpretation, the environmental impact is strongly associated with energy consumption in industry, and it is also connected with the key component of the EV, that is the battery. On the other hand, life cycle assessment is a method intensively used to assess the environmental impact. Closely related are also “country” and “China”, which indicates that the case studies are focused on a certain geographic area, with many studies being conducted by Chinese researchers.

Although the two clusters are well-defined and well-spaced, there is a significant difference between them.

4.2. Conventional Vehicle and CE; the VOSViewer Representation

The VOSViewer network visualization of the text data from the 33 studies selected for this analysis, revealed 3 clusters (Figure 4).

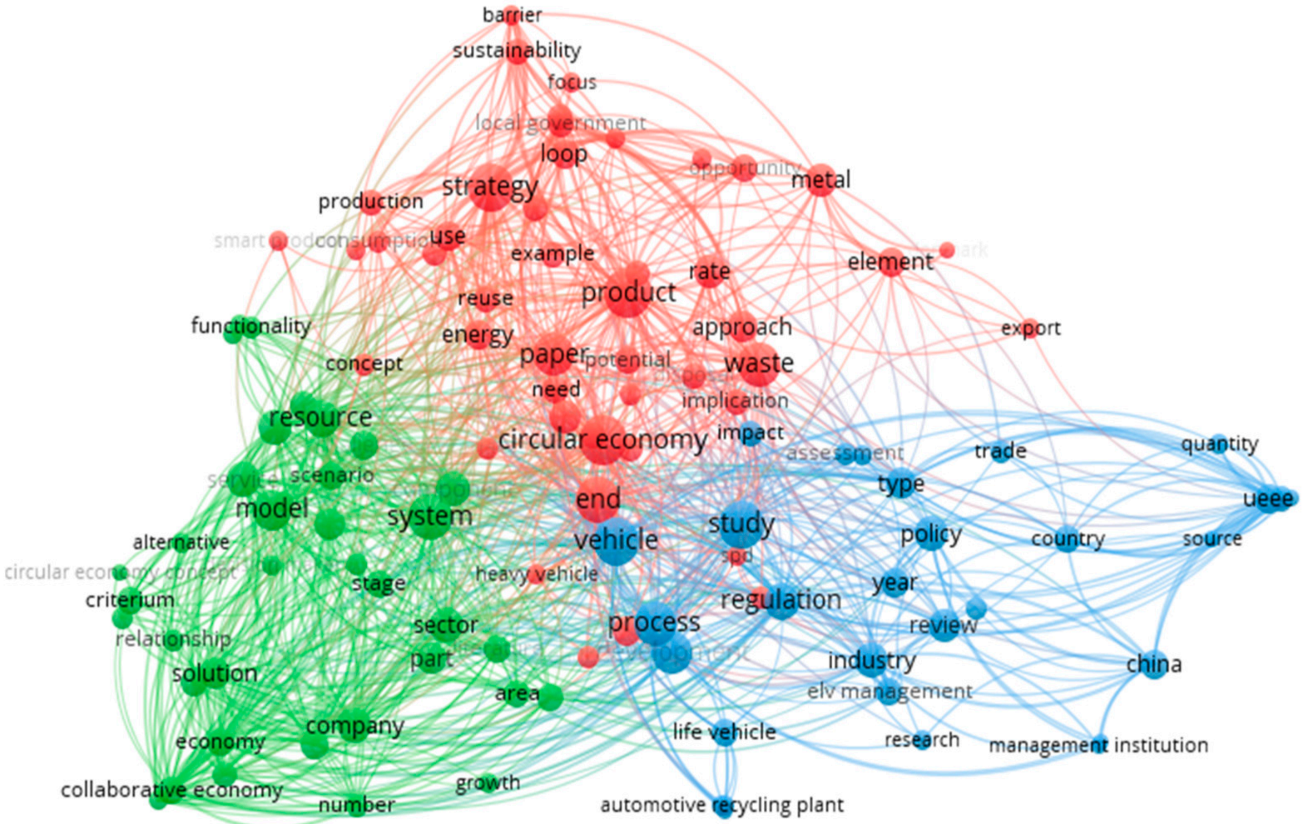


Figure 4. VOSViewer network visualization—CE approaches for CVs (minimum number of co-occurrences—3 and maximum number of terms—115).

The red cluster is centered around the terms "waste", "end", "reuse", and "loop", with increased interest in these studies being related to the EoL stage of the vehicle, waste reduction, and the "zero waste" concept. The appearance of "sustainability" in this cluster, in the marginal area, shows a connection between this concept and that of "CE", where circularity is viewed as a sustainability strategy. The concepts mainly found in the green cluster are "system", "model", "resource", and "solution" while the blue cluster centered around the terms "study", "process", "regulation", and "industry".

5. Conclusions

The number of studies and industrial practices approaching CE for the automotive industry, and the entire life cycle, is still limited, as further research in this direction [10,113] is necessary.

We identified several CE strategies in our review, but a major challenge remains the evaluation of these strategies as to which are the most relevant, effective, and efficient ones, bearing in mind the objective of minimizing the resource functionality loss [107,116].

Future studies should focus on the development and implementation of circularity indicators, and should be able to describe a factual situation and also depict the evolution of trends over time. It is equally interesting to promote new green technologies in the automotive industry, with an emphasis on circularity in terms of raw materials, energy, production systems, product life extension, second use applications, reuse, recycling, and EoLs.

The awareness of environmental barriers, limited energy, and material resources, could stimulate researchers and practitioners into finding new practices in the field [112]. It is also important to identify the extent to which the concept and objectives of the CE are understood by potential stakeholders (such as authorities, waste collection companies, final waste collectors, and also product designers and manufacturers), and to define their vision for improving the automotive industry by implementing the objectives of the CE.

Life cycle assessment is essential for the CE, and it is challenging, due to the large number and diversity of stakeholders. Studies that integrate actors in the supply chain are quite limited, and further dedicated studies are needed [10]. Future directions for the development of the CE should consider: the recycling of raw materials, the extension of the life of products, the reconstruction of resources, the manner of service, and the promotion of sharing instead of purchasing [20,100].

The environmental impact of batteries, secondary users, and the recycling stage [49], constitute additional future research directions, since strategies for battery recycling, and improvement solutions in each stage of the life cycle, are needed, as are standardized CE tools [79].

In subsequent works, close collaboration between the academic and industrial environments is encouraged, in order to identify and implement practices specific to the CE, as well as to communicate commendable practices that are of great importance for improving the remanufacturing processes [114]. Although the European Commission's CE action plan refers, amongst other things, to material recycling and reuse rates, a harmonized indicator is needed between EU member states, to increase the contribution of waste management to CE practices [106]. The strategies considered useful for the implementation of the CE include: new recycling technologies, increasing the use of waste, reuse/remanufacturing, and increasing the utility of the product [12].

It is not necessarily simply "closing the loop", to transition from a linear to a CE, even if this step is important and part of CE. New models should include improvements for each step of the economic model, and outline the associated benefits for society and the environment [6].

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Appendix A. Main Findings—CE Approaches for EVs

Study Objective	Findings	Limitations	Proposals	Reference
A. BATTERY MANAGEMENT				
Overview of the LIB recycling technologies.	Hydrometallurgical regeneration of cathode and direct regeneration can be used for recycling the huge number of LIBs.	There are many challenges, such as cost, safety, environmental friendliness, and energy consumption.	Further studies should focus on the repeatability of the regeneration process to see the quality of cathodes.	[31]
Heterogeneous EVs fleet routing problem with time windows.	The number of small EVs will affect the optimal recycling plan.	The charging problem of EVs is not considered.	The impact of EV charging time should be considered.	[45]
Batteries for electric logistics vehicles (BELVs) are analyzed.	It is necessary to improve vehicle parameters such as the curb mass, all-electric range, energy efficiency, and charging efficiency, and to develop the technology of power exchange and charging.	No complete data on the electricity consumption rates of the various models on the market.	Improve the vehicle performance, reliability, and market penetration of BELVs, and propose new incentive policies.	[46]
The social-economic-environmental impact of recycling retired EV batteries.	Subsidy and reward-penalty policies can help to improve the recycling of retired EV batteries.	China case-study.	More comprehensive environmental assessments may be integrated, especially the local pollutants such as PM10 and PM 2.5.	[51]
A deep review of LIBs and other types of batteries.	Safety concerns and negative environmental impacts of LIBs.	Only LIB type BEV was analyzed in the study.	Issues and challenges about environmental impact, performance, and applications, are highlighted as a basis for further research.	[29]
Sustainable Recycling Technology for LIBs.	Due to the complexity of the battery, secondary pollution such as wastewater, gas, and waste, can occur during the recovery process.	Complex recycling process.	Studies are needed to focus on the environmental impact of batteries, secondary users, and the recycling stage.	[49]
Strategy optimization for recycling batteries.	New EV manufacturers can promote the construction and cooperation of battery recycling sites.	China case-study.	Governments are encouraged to create combined battery recycling strategies, to promote sustainable development.	[36]
Review for electronic waste and EV battery waste.	Bibliometric analysis of research of electronic waste environmental impact.	Limitations regarding keywords selected and databases.	Research in the area of environmental impact of LIBs.	[26]
Environmental footprint for BEV.	The sustainability of the battery pack during production phase is more efficient than other parts with the same weight, if green materials are adopted.	No consideration for energy consumption in the use phase, and also LCA in production and use phase.	More practical perspectives.	[50]

Study Objective	Findings	Limitations	Proposals	Reference
Develop a model for EoL management of BEV based on activity theory.	A source for strategies for sustainable management of EoL batteries.	China case study.	A quantitative analysis of the ecological impact of the LIB EV system.	[27]
Model of battery recycling networks.	Optimization of the design of recycling networks.	Only CO_2 emissions considered in the model.	Other pollutants need to be taken into consideration in the model.	[32]
LIBs circularity and the UK transition to EVs.	Circularity is the way for low carbon technologies.	UK case study.	Integrate 'circular novel thinking'	[42]
Use of several methodologies for environmental impact assessment of LIBs.	Multi-criteria analysis is beneficial for complex systems.	It does not include some aspects, such as different deployment scenarios, or improved EoL practices.	More research needed due to lack of information for LIBs.	[43]
A review of LIB manufacturing.	Explain the complexity, challenges, and opportunities for LIBs.	Complexity of the subject.	The need for more detailed data on environmental impacts.	[54]
Lifecycle environmental impact assessment for battery system life cycle stages.	A set of 10 principles is proposed for increasing environmental impact of battery application.	LCA models depend on policy and market drivers.	Develop new solution for environmental sustainability.	[52]
Evaluate a LABs recycling firm in Yunnan to quantify the emissions impact.	Recycling system could not achieve sustainable development goals because of the dependence on non-renewable resources.	A company case study.	Policies to improve these types of systems.	[30]
Investigate a closed loop system for the rare elements in electric batteries for Europe.	A CE model for earth elements is beneficial in terms of resource depletion, and it reduces supply risk.	It is limited to the rare elements, without taking into account the other components of the battery (e.g., metals), or the uncertainty of new future recycling methods.	Future business models for used batteries focusing more on second use than recycling.	[21]
Investigate recycling and reuse of batteries from EVs.	A strategy for the CE could be to adapt facilities for both recycling, and testing batteries for second life.	Theoretical investigation of EV battery recycle and reuse.	Detailed studies for each of the battery reuse applications.	[7]
A review to investigate the recycling of LIBs.	Green aspects of the recovery process of LIBs, and the importance of cell design to a more efficient recycling process.	Study specific to a single product type—LIB recycling.	Extending this type of review to other products.	[33]
Demonstration and evaluation of CE strategy for LIBs.	Circular resource planning and distribution model developed.	The case study is for Berlin, Germany.	Extended for other areas.	[47]

Study Objective	**Findings**	**Limitations**	**Proposals**	**Reference**
A review that demonstrates the need for government policies to manage LIBs at the end of the life cycle.	It offers potential solutions through CE models that are based on property models (LIB to be owned by producers even during consumer use).	The data are based on currently uncertain assumptions about market evolution and battery life.	Further studies on the topic and future data are needed in order to decide on the benefits of the CE through direct recycling of LIBs.	[48]
Analyses of processes for the treatment of post-use LIBs by approaching the CE.	There are great challenges, both economically and environmentally, that will appear in the future, with the increase in the number of batteries.	Precarious legislative framework regarding spent batteries.	For a CE model, it is necessary to design products that are easily reused and recycled.	[25]
Development of a sustainable business model for second use battery for EVs.	In the emerging B2U (Battery Second Use) market, stakeholders integrate sustainable value creation activities into sustainable business processes.	Was applied only for second use battery case for EVs.	Development of sustainable business model.	[38]
Reusing used batteries from EVs in buildings as stationary storage systems.	Old batteries from EVs can be used for the building sector.	Limited data are available about the parameters of the energy model e.g., charge/discharge efficiency, battery capacity degradation, and battery lifetime.	More studies on sustainability of the second life of used batteries.	[40]
CE perspective on the reuse and recycling of LIBs.	Reuse and recycling of LIBs is a necessity.	The review is limited to reuse and recycling of the LIBs.	The study is helpful for policy makers to use in updating policies for energy transition.	[44]
Second life applications for EV batteries.	There are organizational and cognitive barriers for second life applications for BEVs.	Several unexplored aspects during the interviews with stakeholders.	Further research from the technical, economic, and organizational perspectives, regarding the stage of production and use of the battery, in order to identify strategies with added value.	[39]
LCA for BEVs in second use applications.	There are environmental benefits to extending an EV battery's lifetime.	Lack of data regarding the repurposing stage.	Environmental assessments should be considered, in order to provide a complete overview of the sustainability of reuse.	[41]
Improvements to EoL management of LIBs in the US.	Provides a set of EoL management recommendations for the US on policy, infrastructure, and technology.	US case-study.	Determine urgent aspects regarding policy, infrastructure, and technology.	[28]
Recycling methods for LIBs.	Many papers are focusing on recycling and recovery-related issues.	Most of the studies were experimental.	Further techno-economic assessment of the recycling process, safe reverse logistics, and a global EV assessment, thus revealing material recovery potential.	[34]

Study Objective	Findings	Limitations	Proposals	Reference
Adapt manufacturing processes for the coming cell chemistries and components regarding BEVs.	Current practices in material collection, sorting, transportation, handling, and recycling.	One limitation is represented by constantly changing the composition.	For Li–metal and Li–S batteries, the reactivity of the materials will bring up safety concerns during recycling.	[55]
A perspective regarding the LIB recycling process.	Synthesis of challenges associated with LIBs recycling.	Technical, policy and economic and ecological considerations.	Practical suggestion for a CE for LIBs.	[37]
Battery recycling network perspective.	Remanufacturing, reuse and recycling strategies for LIBs.	Chinese company case-study.	A recycling network model is developed in order to minimize the total cost and carbon emissions.	[35]
Evaluation of LIBs' environmental impact.	Renewable energy for electricity maximizes environmental benefits.	LIB industry is very complex.	Electricity generation source determine EV emissions.	[53]
B. VEHICLE MANAGEMENT				
Changes after replacing the cars with 100% EVs.	Electric mobility and renewable energies as possible approaches for "zero emissions" concept.	A case study on a Portuguese business campus.	Extend application to other areas.	[58]
Analysis of vehicle emissions correlated with energy use and climate change.	The impact of vehicle emissions, energy use, and climate change, on the environment and human health.	Ghana case-study.	It is necessary to create and apply policies in sectors such as transport, environment, and energy.	[59]
Digital twin technology review.	Digital twin technologies adapted for smart electric vehicle use cases are described.	Modeling complex systems is a limitation.	Further work can begin with the identified technologies for sustainable development.	[64]
Apply the sustainability optimization framework to the supply chain for the automotive industry in Europe.	The automotive industry has the potential to improve sustainability, considering that labor costs and emissions achieve a major impact in the manufacturing stage	The study is conducted on the European car industry.	Detailed model for electric vehicle components and determination of emission factors specific to various European countries.	[67]
Analyzing if strategy adopted in the city of Dundee regarding EVs, is beneficial for reducing carbon emissions.	An ecological plan of the local authorities leads in the direction of meeting the objectives of Agenda 30 SDG.	Applied to one city.	Forthcoming studies on how DGS objectives are implemented.	[60]
Develop an emission index.	An electric light truck emissions index that measure greenhouse gas (GHG) emissions, was established.	China case study.	Different perspectives based on the created index can offer suggestions regarding GHG emissions research.	[18]

Study Objective	**Findings**	**Limitations**	**Proposals**	**Reference**
Analyzing the EV recycling process.	Preparation of materials for recycling is conducted in a small number of companies, mostly using metals.	Some limitations include disassembling, and the structure of the vehicle.	Improvement of the EV recycling and energy recovery sustainability model. Greater inclusion of leadership factors in the model of sustainable EV recycling.	[65]
SWOT and PESTL methodologies for strategies for five countries regarding e-mobility in European regions.	Positive changes in EVs.	Limitations regarding the number of countries analyzed.	Optimize strategies for e-mobility.	[61]
Investigation regarding optimal decisions from EV manufacturing, and government subsidies, from social point of view.	Environmental impact performance is not necessarily increasing after introducing EVs.	Considered only manufacturers for EVs and also conventional vehicles.	Discrepancy between manufacturers and governments; different rules from government regarding reward and punishment.	[63]
Evaluation of sustainability for EVs.	Sustainability is considered an end indicator.	Research review methodology.	A better approach to the interaction between sustainability and EV systems.	[56]
Highlighting how CE strategies can reduce the extraction of raw materials (e.g., cobalt).	The best CE strategies are the new substitution technologies.	The scope is limited to the European Union.	Development of new strategies, both at government and business level.	[57]
Attempt to identify the trends and factors that affect the performance of the 3R system for the BEV.	Highlight factors that affect 3R system design and performance.	Empirical sources from the study were mainly Swedish and European.	3R system modeling for BEV considers factors that may affect the system over time.	[66]
A review of ways to recycle EVs.	that the battery is the element of the recycling process that is worth the most.	Limited future estimates of EV flows and limited assessment of stakeholder relationships in the reverse supply chain.	Focus on other components of worth that can be recycled from EV components.	[13]
A review of business models for battery second use.	The necessity of a multi-stakeholder network-centric business model.	Most BEVs will be retired after several years.	Development of a business model that highlights the relationships between stakeholders, especially OEM (Original Equipment Manufacturer) and battery second use service providers.	[22]
Ways to adopt an integrated life cycle approach.	Gaps identified in socio-economic assessment, macro-level assessment, and CE applications.	Only the Scopus database was considered.	State-of-the-art and practice of emerging technologies and EVs in the field of LCA.	[62]
C. LIFE CYCLE SUSTAINABLE ASSESSMENT				

Study Objective	Findings	Limitations	Proposals	Reference
A comparison between CVs and EVs.	The environmental benefits of EVs are higher than the environmental benefits of CVs.	Vehicles from China are selected for the model.	Future work should be focused on different types of vehicles.	[78]
Macro-sustainability assessment for alternative vehicles in the US.	EVs have less air pollution compared to others vehicles.	Applications of the life cycle sustainable assessment method are limited in a real case study.	Models that include temporal and spatial variations should be integrated.	[68]
Comparison of environmental impacts of EVs vs. CVs.	The developed method is used for analysis of environmental effects of new technologies.	Considered only a few pollutants, and just two types of vehicles.	Waste collection to be investigated.	[69]
Model to quantify sustainability indicators using LCSA and multi-criteria decision- making.	Using solar energy for BEVs reduces environmental impacts.	Vehicle manufacturing and disposal phases are not considered.	The Qatar case study to be extended for other countries.	[108]
Assessment of life cycle sustainability in China.	According to LCA, the comprehensive impact value of the resource environment of the life cycle of the BEVs is higher than in the case of ICEVs (Internal Combustion Engine Vehicle).	China case study and some assumptions that may vary from reality.	Expanding the scope.	[70]
Multi-regional input-output based Life Cycle Sustainability Assessment framework model.	BEVs have a lower impact, in terms of global warming potential, particle formation, and photochemistry oxidant formation.	Vehicle manufacturing and EoL are not analyzed.	The model can be developed by making a connection between the three sustainability pillars (not only separately analyzing the indicators).	[109]
Proposed a model for evaluating environmental, social, and economic impacts of EV.	The importance of the three pillars model.	The simulation did not take into account the upward trend of acquisitions; the market share was considered constant over time.	New studies regarding the increased trend of sales markets for EVs, and relation to pollutants.	[73]
Environmental impact evaluation for EVs.	BEVs have the smallest environmental impacts.	Brasilia case study.	Extend to other areas.	[74]
Comparison between EVs and ICEVs.	The manufacturing and disposal of electronics and batteries, and also energy consumption and rare earth elements used in those processes, are detrimental to the environment.	Some assumptions and delimitations on life cycle stages.	It is necessary to close the loop, in terms of raw materials and rare earth elements.	[75]
Investigation of whether nonmaterial brings a positive environmental impact for EVs.	It was found that using environmentally friendly materials in the extraction and production phase, brings disadvantages to the environment in the use phase, and vice versa.	Data's limitations in LCA.	Collaboration between nanotechnology, nanotoxicology, eco-design, and green chemistry, for the transport sector.	[76]

Study Objective	**Findings**	**Limitations**	**Proposals**	**Reference**
LCA comparison between EVs and ICEVs from an environmental perspective.	The BEV manufacturing stage still has a major impact on the environment.	Dates used are taken from literature, studies, and existing dates.	BEV improvement of technological efficiency.	[77]
Assessment of EV sustainability, from the design stage.	Cobalt is an important element in the manufacturing of batteries, and great care is needed to avoid its depletion.	There is limited knowledge in the design stage.	The assessment can also be used for other types of products.	[71]
Developing an integrated and dynamic life cycle sustainability assessment framework for EVs.	Environmental impacts of BEVs are highest in the manufacturing phase, compared to manufacturing phase impacts of ICEVs.	Estimation of the sustainability impact of vehicle options are limited by narrow system boundaries.	Exploratory modeling and analysis should be integrated in the model.	[72]
Identify the most used CE strategies.	LCA-supported CE has not been sufficiently explored.	Standardized CE and LCA tools and indicators need to be developed.	Create circular models to improve the overall resource efficiency of electromobility.	[79]
D. TRANSPORT MANAGEMENT				
Highlight policies for EVs.	Environmental and industrial goals: a decrease in GHG emissions.	Study focused on Germany and the UK.	Additional research on more precise pathways, as well as the quantification of further aspects, could lead to a more extensive analysis.	[80]
Identify the best alternatives for sustainable transport.	The connected electric vehicle is considered to be the most sustainable option for public transport.	Others factors should be considered aside from those mentioned in the study.	Review the multi-criteria decision model proposed in this analysis, considering limitation, changes in the automotive industry, and fuel alternatives.	[81]
The scope is to develop public transport using electric buses.	It is considered that the lack of funds for the maintenance of BEVs could affect public transport with EVs.	Poland case-study.	Differences compared to other countries.	[82]
Create a model for green public procurement.	Biomethane solutions may be linked to positive environmental effects.	Sweden case-study.	Apply to another context.	[83]
Develop charging strategies.	Renewable power consumption, netload valley filling, and minimizing charging costs, can reduce emissions.	A perfect collaboration between EV owners.	Identify how limitations can impact results.	[84]
E. CONSUMER BEHAVIOR				

Study Objective	Findings	Limitations	Proposals	Reference
Investigate the factors affecting consumers' intentions to adopt EVs.	Results show the factors which affect consumers' intentions to buy EVs.	Limitations may be represented by the need to use other theories, such as the model of technological acceptance, in order to see the impact of other factors.	Other methods of data analysis, such as machine learning and multi-criteria decision-making, should be used.	[86]
The need to understand the gap in green purchasing behavior.	Proposes using the model of Motivation—Intention—Context–Behavior, to explain the driving factors behind green purchases.	Applied to China.	Finding out and simulating various policies for green procurement.	[85]
Determine the factors that influence the purchase of EVs.	Manufacturers should take steps to better promote EVs.	The case study refers to consumers in China.	Connect industry with consumers, from the industrial and technological perspectives of EVs.	[87]
Survey to analyze consumer interests in a CE for the automotive industry, especially durable tires	The results of the study show that perceptions of climate change, using test reports or assessment portals, are variable, and related to the configuration preferences of software for sustainable automotive products.	The limits are represented by an online survey applied in Germany before the onset of the COVID-19 crisis.	Future studies to assess consumer preferences following incentives for new car purchases, and to evaluate target groups interested in purchasing sustainable cars.	[4]
F. ELECTRICITY RENEWABLE SOURCES AND CHARGING INFRASTRUCTURE				
Propose a methodology for sustainability.	Development of a methodology to demonstrate sustainability for EVs regarding CO_2 emissions.	It is limited to Spain, and only to CO_2 emissions.	Extension for possible electrification in transport.	[117]
Highlight the environmental impact of electric power production for BEVs, five countries being compared	GHG quantity for a BEV is dependent on the power generation technology.	The study is based on data for five European countries.	Extend to other countries.	[88]
Estimation of environmental impact for four types of chargers.	Quantity of chargers is mainly affected by the electricity mix, types, and quantities of chargers.	Many factors affect the increase of chargers.	Combine the LCA of charging infrastructure, with management and economics methodology (organizational strategies and reward-driven systems).	[89]
Develop a model regarding external costs, including emissions and time losses, with societal and consumer life cycle costs.	The EV has the lowest life cycle cost, due to the low cost of electricity.	Estimation of data from different models.	Include some other criteria.	[90]

Study Objective	Findings	Limitations	Proposals	Reference
G. RAW MATERIALS				
Impact of the EV on the lithium market.	Uncertainties related to the environmental impact of lithium production.	The model does not consider recycling and remanufacturing.	The model should consider remanufacturing and recycling infrastructures, and the model can be used for other materials (non-ferrous and rare-earth metals).	[91]
Develop a Multi-Regional Input-Output, based on LCA approach.	Manufacturing phase dominates the life-cycle material footprints of vehicles.	Predefined data used.	System dynamic approach.	[92]
Eco-efficiency analysis for LIB waste.	LCA and eco-efficiency are important for determining the greatest environmental benefits under a CE-inspired waste management hierarchy for EoL LIBs.	It is a case study applied to a theoretical stream of 1000 LIBs.	Industry will still require technology development, to create collection programs and improve metal recovery.	[93]
Material flow analysis for lithium.	In 2015, China's lithium consumption was 50% of the total amount.	China case-study.	Big quantities of lithium stocked in LIBs, brings an opportunity for lithium recycling, from a circularity perspective.	[94]
H. AIR POLLUTION REDUCTION STRATEGIES				
An evaluation of EV air pollution in India.	In order to increase the purchase of EVs, different government policies are recommended, depending on the social class.	A review for India.	Extend the review for other areas.	[95]
Strategies to reduce carbon emissions by using the CE.	The increased demand for lithium will generate an imbalance by 2050, which will affect the BEV market and will also increase CO_2 emissions.	Social-environmental consequences for critical material supply should be included in the model.	Creating a model to increase recycling rates that probably require energy consumption, which leads to increased emissions.	[96]
I. ECO-DESIGN (TECHNICAL DESIGN CHANGES)				
Predictions regarding HEV/EV.	Predictions regarding HEV/EV stock evolution to reduce GHG emissions.	Technical aspects of EVs, such as efficiency, reliability, autonomy, and cost, must be improved.	Alternative cooling architectures, (spray cooling, jet impingement cooling, heat pipes, etc.) should be investigated for implementation in real EVs.	[97]
Components modification for EVs, in order to increase environmental sustainability.	For eco-design, choice of material is important. Use of lighter materials, reduces fuel consumption.	Limitations of the study consist of the various estimates and assumptions contained therein.	The development of a product configurator, to support design.	[98]

Appendix B. Main Findings—CE Approaches for CVs

Study Objective	Findings	Limitations	Proposals	Reference
A. CE STRATEGIES				
Evaluate and discover a correlation, in terms of a freight transport system.	Prioritization list of CE concepts.	Complexity of the model and complex mathematical apparatus for calculating relational relationships between criteria.	Development of an adaptive decision-making tool based on the fuzzy DIBR-D'CoCoSo methodology.	[101]
CE strategy implications for sustainable development of products.	Greater emphasis on addressing the CE during strategic product planning and task clarification activities.	Lack of information concerning products' EOL.	It is recommended in existing decision-making support, for example, by adding circularity indicators in product evaluation comparison tables.	[6]
An example of planning the supply of spare parts.	Model of the reverse logistic chain.	Some limitations on model indicators (weight of spare parts, physical volume spare parts, etc.).	Reverse logistics for a CE system.	[2]
CE strategies.	ICEVs use ∼6% renewable life cycle primary energy, and 27% recycled materials.	Consider material efficiency, reusing and recycling parts, vehicle design, shared mobility, and low-carbon technologies for CE strategies.	Further studies for developing targeted CE strategies.	[116]
Analysis of 20 crucial roadblocks hindering CE implementation in Indian automobile companies.	The top roadblocks analyzed are 'lacking ability to deliver high quality remanufactured products', 'maintaining the design of reuse product', 'lack of awareness in society' and 'lack of consumer knowledge about refurbished products'.	Case-study on Indian automobile companies.	Extend to other countries.	[5]
Structured group multi-criteria decision-making methods MCDM) for evaluation of stakeholders' cooperation.	MCDM methods and the CE combined together for new results.	Small sample of two empirical group MCDM exercises.	New studies bringing together several actors from a supply chain, necessary for information exchange.	[10]
Effectiveness of product-based circularity, using the Material Circularity Indicator and Product Circularity Indicator.	Regulation has limited effects on realizing material circularity in the automotive industry.	Study is using only 2 indicators.	Develop effective CE strategies from a holistic life cycle approach, particularly through more scrap utilization, higher intensity of vehicle uses, and design for reuse/remanufacturing.	[12]

Study Objective	Findings	Limitations	Proposals	Reference
Identify the parameters used for material efficiency potentials and pathways of socio-economic development, and also to improve existing methods and processes.	Different scenarios for the potential greenhouse gas abatement that could be achieved by 2050, through the deployment of different combinations of ten strategies in several counties.	Limit the scope of assessment to large, regional, resolutions.	Extend the presented scenarios.	[102]
Find technical solution for non-metallic parts to maximize recyclability and recoverability.	A CE-updated strategy is necessary, including raw material recycling, resource reconstruction, extended product life, product service, and transformation from individual ownership to multi-person sharing.	Metallic parts are not included.	New studies regarding the strategies for CE.	[100]
Maximal potential recycling of EV steel, by exploring the utilization methods of scrap, sorted by parts, to produce crude alloy steel, with minimal losses of alloying elements.	Parts-based scrap sorting could bring a recovery of 94−98% of the alloying elements from parts scrap.	Japan case-study.	Redefining CE policies so as to engage industries that use recycled materials, as well as recyclers and manufacturers of products subject to recycling.	[99]
B. RECYCLING MANAGEMENT				
Study the innovation of vehicle recycling in Italy.	Facilities for automotive recycling necessity.	Italy case-study.	Automotive recycling center could be an instrument and operational source for environment protection.	[103]
Study that focuses on the separation of recycling rates into the following categories: closed-loop collection rate, open-loop collection rate, and recycling rate.	Collection rates represent collected material that enters the recycling process, and recycle rates measure the available secondary resources produced from recycling processes.	Switzerland case-study.	Currently used rates are not suitable as a performance indicator for a CE.	[106]
Remanufacturing for CE.	Remanufacturing is an important sector for green development, with cost reduction, energy and material savings.	China case-study.	Define responsibility of management institutions, modify the legal and standards system, launch tax incentives for remanufactured products, and standardized reverse logistics system.	[24]

Study Objective	Findings	Limitations	Proposals	Reference
Database for scrap of three bulk metals (iron and steel, aluminum and copper).	Quantities of alloying elements can be considerable. Alloying elements such as Cr, Zn, Mn, Cu, Sn, Ni, and Pb, have an aggregated weight in the three scrap metals that was higher than 2 kt in the year 2017.	Denmark case study.	Identify how trade of scrap metals affects recycling and efficiency pathways.	[104]
Identify critical components of recycling business model.	Recycling process reduces carbon footprint.	Web of Science and ScienceDirect databases.	Practical solutions for new business models.	[105]
C. RAW MATERIALS				
Hierarchical level description—substance level (elements and compound)—circularity reference level method.	Multilevel Statistical Entropy Analysis allows the degree of circularity of material flow systems to be evaluated in the context of combinations of different CE strategies.	The mixing component between substances and raw material extraction is not considered.	Further studies should focus on different levels of products, components, and materials, in order to be applicable for reuse (non-destructive) and recycle (destructive) strategies.	[107]
The Statistical Entropy Analysis (SEA) method is used to evaluate the use of resources and the functionality of the product over time, and also to indicate which of the EC strategies keeps the functionality at the maximum level, with minimum effort.	SEA has the role of quantifying the effects of CE strategies.	The case study employed vehicles with a simplified vehicle composition, and only proposed basic CE strategies.	Include export and import of vehicles, also raw material processing.	[11]
Evaluation of the metals included in the vehicle, including downcycling.	Even if quantity of downcycled metals represents 4.5% of the total metal weight of the vehicle, in rarity terms, this figure increases to approximately 27%.	Macro assessment done for the evaluation of the metals.	Changing the eco-design to favor the easier disassembly required at the end of life.	[110]
D. EOL MANAGEMENT				
Improvement in the EoL of heavy vehicles, from the dismantling to the economic recovery.	EoL alternative(s) for the used heavy vehicles collected and for the components recovered after the dismantling operations.	Industrial pilot study case.	Improvement solutions and support tools for EoL.	[114]
Identify gaps and further research for EoL vehicle management systems.	Literature review of the EoL management system.	Limitation regarding method review criteria: period 2000–2019.	To document industry practices in case studies or surveys and identify environmental consequences regarding extending the EV logistics network.	[113]

Study Objective	Findings	Limitations	Proposals	Reference
The aim is to quantify recyclability and recoverability at the EoL of the material used.	It has been found that better recycling and recovery processes are needed for better recycling and recovery.	South Korea case-study.	a collaboration between the manufacturer and the recycler is recommended, in order to take into account the feedback of the recycler regarding the separation of the material and the incompatibility of mixing the materials.	[115]
The aim is to determine how many components can be hypothetically manufactured, and whether a dedicated recycling program for the components of interest, is feasible.	Some opportunities include: develop components that can be remanufactured or repaired, and collect sorted components for dedicated and functional recycling.	Only two components of the vehicle included in the case study (wheel component and gearbox component).	In order to increase recycling programs and the implementation of CE policies, it is necessary for there to be collaboration between stakeholders.	[111]
Policies for recycled EoL vehicles.	Value added tax and a deposit-refund system would stimulate a higher recycle process, at 80% until 2050.	China case-study.	New studies should include case studies for specific cities or companies in the automotive industry, as well as waste chain research.	[112]

References

1. Capgemini Research Institute. *The Automotive Industry in the Era of Sustainability Executive Summary*; Capgemini Research Institute: Paris, France, 2020.
2. Makarova, I.; Shubenkova, K.; Buyvol, P.; Shepelev, V.; Gritsenko, A. The role of reverse logistics in the transition to a circular economy: Case study of automotive spare parts logistics. *FME Trans.* **2021**, *49*, 173–185. [CrossRef]
3. Belmonte-Ureña, L.J.; Plaza-Úbeda, J.A.; Vazquez-Brust, D.; Yakovleva, N. Circular economy, degrowth and green growth as pathways for research on sustainable development goals: A global analysis and future agenda. *Ecol. Econ.* **2021**, *185*, 107050. [CrossRef]
4. Wurster, S.; Heß, P.; Nauruschat, M.; Jütting, M. Sustainable Circular Mobility: User-Integrated Innovation and Specifics of Electric Vehicle Owners. *Sustainability* **2020**, *12*, 7900. [CrossRef]
5. Agrawal, R.; Wankhede, V.A.; Kumar, A.; Luthra, S. Analysing the roadblocks of circular economy adoption in the automobile sector: Reducing waste and environmental perspectives. *Bus. Strat. Environ.* **2020**, *30*, 1051–1066. [CrossRef]
6. Diaz, A.; Schöggl, J.-P.; Reyes, T.; Baumgartner, R.J. Sustainable product development in a circular economy: Implications for products, actors, decision-making support and lifecycle information management. *Sustain. Prod. Consum.* **2021**, *26*, 1031–1045. [CrossRef]
7. Kotak, Y.; Fernández, C.M.; Casals, L.C.; Kotak, B.; Koch, D.; Geisbauer, C.; Trilla, L.; Gómez-Núñez, A.; Schweiger, H.-G. End of Electric Vehicle Batteries: Reuse vs. Recycle. *Energies* **2021**, *14*, 2217. [CrossRef]
8. Dominish, E.; Retamal, M.; Sharpe, S.; Lane, R.; Rhamdhani, M.A.; Corder, G.; Giurco, D.; Florin, N. "Slowing" and "Narrowing" the Flow of Metals for Consumer Goods: Evaluating Opportunities and Barriers. *Sustainability* **2018**, *10*, 1096. [CrossRef]
9. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, E.J. The circular economy—A new sustainability paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [CrossRef]
10. Bachér, J.; Pihkola, H.; Kujanpää, L.; Mroueh, U.-M. Advancing the circular economy through group decision-making and stakeholder involvement. *Detritus* **2018**, *4*, 22–35. [CrossRef]
11. Parchomenko, A.; Nelen, D.; Gillabel, J.; Vrancken, K.C.; Rechberger, H. Resource effectiveness of the European automotive sector—a statistical entropy analysis over time. *Resour. Conserv. Recycl.* **2021**, *169*, 105558. [CrossRef]
12. Soo, V.K.; Doolan, M.; Compston, P.; Duflou, J.R.; Peeters, J.; Umeda, Y. The influence of end-of-life regulation on vehicle material circularity: A comparison of Europe, Japan, Australia and the US. *Resour. Conserv. Recycl.* **2020**, *168*, 105294. [CrossRef]
13. D'Adamo, I.; Rosa, P. A Structured Literature Review on Obsolete Electric Vehicles Management Practices. *Sustainability* **2019**, *11*, 6876. [CrossRef]
14. Sadik-Zada, E.R.; Gonzalez, E.D.S.; Gatto, A.; Althaus, T.; Quliyev, F. Pathways to the hydrogen mobility futures in German public transportation: A scenario analysis. *Renew. Energy* **2023**, *205*, 384–392. [CrossRef]
15. Golinska, P.; Kosacka, M. Environmental Friendly Practices in the Automotive Industry. *Environ. Issues Automot. Ind.* **2013**, 3–22. [CrossRef]
16. Grigore, N.A.; Kifor, C.V. Are electric vehicles eco-friendly products? A review from life cycle and sustainability perspective. *MATEC Web Conf.* **2021**, *343*, 07002. [CrossRef]
17. Hong, J.; Wang, Z.; Zhang, T.; Yin, H.; Zhang, H.; Huo, W.; Zhang, Y.; Li, Y. Research on integration simulation and balance control of a novel load isolated pure electric driving system. *Energy* **2019**, *189*, 116220. [CrossRef]
18. Li, J.; Yang, B. Quantifying the effects of vehicle technical performance and electricity carbon intensity on greenhouse gas emissions from electric light truck: A case study of China. *Atmos. Pollut. Res.* **2020**, *11*, 1290–1302. [CrossRef]
19. Gosens, J. The greening of South-South trade: Levels, growth, and specialization of trade in clean energy technologies between countries in the global South. *Renew. Energy* **2020**, *160*, 931–943. [CrossRef]
20. Sadik-Zada, E.R.; Gatto, A.; Scharfenstein, M. Sustainable management of lithium and green hydrogen and long-run perspectives of electromobility. *Technol. Forecast. Soc. Chang.* **2023**, *186*, 121992. [CrossRef]
21. Silvestri, L.; Forcina, A.; Silvestri, C.; Traverso, M. Circularity potential of rare earths for sustainable mobility: Recent developments, challenges and future prospects. *J. Clean. Prod.* **2021**, *292*, 126089. [CrossRef]
22. Reinhardt, R.; Christodoulou, I.; Gassó-Domingo, S.; García, B.A. Towards sustainable business models for electric vehicle battery second use: A critical review. *J. Environ. Manag.* **2019**, *245*, 432–446. [CrossRef]
23. Merli, R.; Preziosi, M.; Acampora, A. How do scholars approach the circular economy? A systematic literature review. *J. Clean. Prod.* **2018**, *178*, 703–722. [CrossRef]
24. Yuan, X.; Liu, M.; Yuan, Q.; Fan, X.; Teng, Y.; Fu, J.; Ma, Q.; Wang, Q.; Zuo, J. Transitioning China to a circular economy through remanufacturing: A comprehensive review of the management institutions and policy system. *Resour. Conserv. Recycl.* **2020**, *161*, 104920. [CrossRef]
25. Mossali, E.; Picone, N.; Gentilini, L.; Rodrìguez, O.; Pérez, J.M.; Colledani, M. Lithium-ion batteries towards circular economy: A literature review of opportunities and issues of recycling treatments. *J. Environ. Manag.* **2020**, *264*, 110500. [CrossRef]
26. Preeti, M.; Sayali, A. Scientometric Analysis of Research on End-oflife Electronic Waste and Electric Vehicle Battery Waste. *J. Sci. Res.* **2021**, *10*, 37–46. [CrossRef]
27. Li, J.; Qiao, Z.; Simeone, A.; Bao, J.; Zhang, Y. An activity theory-based analysis approach for end-of-life management of electric vehicle batteries. *Resour. Conserv. Recycl.* **2020**, *162*, 105040. [CrossRef]

28. Meegoda, J.N.; Malladi, S.; Zayas, I.C. End-of-Life Management of Electric Vehicle Lithium-Ion Batteries in the United States. *Clean Technol.* **2022**, *4*, 1162–1174. [CrossRef]
29. Hannan, M.A.; Hoque, M.D.M.; Hussain, A.; Yusof, Y.; Ker, A.P.J. State-of-the-Art and Energy Management System of Lithium-Ion Batteries in Electric Vehicle Applications: Issues and Recommendations. *IEEE Access Spec. Sect. Adv. Energy Storage Technol. Appl.* **2018**, *6*, 19362–19378. [CrossRef]
30. Pan, H.; Geng, Y.; Dong, H.; Ali, M.; Xiao, S. Sustainability evaluation of secondary lead production from spent lead acid batteries recycling. *Resour. Conserv. Recycl.* **2018**, *140*, 13–22. [CrossRef]
31. Wang, Y.; An, N.; Wen, L.; Wang, L.; Jiang, X.; Hou, F.; Yin, Y.; Liang, J. Recent progress on the recycling technology of Li-ion batteries. *J. Energy Chem.* **2020**, *55*, 391–419. [CrossRef]
32. Wang, L.; Wang, X.; Yang, W. Optimal design of electric vehicle battery recycling network—From the perspective of electric vehicle manufacturers. *Appl. Energy* **2020**, *275*, 115328. [CrossRef]
33. Thompson, D.L.; Hartley, J.M.; Lambert, S.M.; Shiref, M.; Harper, G.D.J.; Kendrick, E.; Anderson, P.; Ryder, K.S.; Gaines, L.; Abbott, A.P. The importance of design in lithium ion battery recycling—A critical review. *Green Chem.* **2020**, *22*, 7585–7603. [CrossRef]
34. Islam, T.; Iyer-Raniga, U. Lithium-Ion Battery Recycling in the Circular Economy: A Review. *Recycling* **2022**, *7*, 33. [CrossRef]
35. Hu, X.; Yan, W.; Zhang, X.; Feng, Z.; Wang, Y.; Ying, B.; Zhang, H. LRP-Based Design of Sustainable Recycling Network for Electric Vehicle Batteries. *Processes* **2022**, *10*, 273. [CrossRef]
36. Lyu, X.; Xu, Y.; Sun, D. An Evolutionary Game Research on Cooperation Mode of the NEV Power Battery Recycling and Gradient Utilization Alliance in the Context of China's NEV Power Battery Retired Tide. *Sustainability* **2021**, *13*, 4165. [CrossRef]
37. Yu, X.; Li, W.; Gupta, V.; Gao, H.; Tran, D.; Sarwar, S.; Chen, Z. Current Challenges in Efficient Lithium-Ion Batteries' Recycling: A Perspective. *Glob. Chall.* **2022**, *6*, 2200099. [CrossRef]
38. Reinhardt, R.; Christodoulou, I.; García, B.A.; Gassó-Domingo, S. Sustainable business model archetypes for the electric vehicle battery second use industry: Towards a conceptual framework. *J. Clean. Prod.* **2020**, *254*, 119994. [CrossRef]
39. Olsson, L.; Fallahi, S.; Schnurr, M.; Diener, D.; van Loon, P. Circular Business Models for Extended EV Battery Life. *Batteries* **2018**, *4*, 57. [CrossRef]
40. Cusenza, M.A.; Guarino, F.; Longo, S.; Ferraro, M.; Cellura, M. Energy and environmental benefits of circular economy strategies: The case study of reusing used batteries from electric vehicles. *J. Energy Storage* **2019**, *25*, 100845. [CrossRef]
41. Bobba, S.; Mathieux, F.; Ardente, F.; Blengini, G.A.; Cusenza, M.A.; Podias, A.; Pfrang, A. Life Cycle Assessment of repurposed electric vehicle batteries: An adapted method based on modelling energy flows. *J. Energy Storage* **2018**, *19*, 213–225. [CrossRef]
42. Bonsu, N.O. Towards a circular and low-carbon economy: Insights from the transitioning to electric vehicles and net zero economy. *J. Clean. Prod.* **2020**, *256*, 120659. [CrossRef]
43. Bobba, S.; Bianco, I.; Eynard, U.; Carrara, S.; Mathieux, F.; Blengini, G.A. Bridging Tools to Better Understand Environmental Performances and Raw Materials Supply of Traction Batteries in the Future EU Fleet. *Energies* **2020**, *13*, 2513. [CrossRef]
44. Pagliaro, M.; Meneguzzo, F. Lithium battery reusing and recycling: A circular economy insight. *Heliyon* **2019**, *5*, e01866. [CrossRef]
45. Cao, S.; Liao, W.; Huang, Y. Heterogeneous fleet recyclables collection routing optimization in a two-echelon collaborative reverse logistics network from circular economic and environmental perspective. *Sci. Total. Environ.* **2021**, *758*, 144062. [CrossRef] [PubMed]
46. Jiang, X.; Guo, X. Evaluation of Performance and Technological Characteristics of Battery Electric Logistics Vehicles: China as a Case Study. *Energies* **2020**, *13*, 2455. [CrossRef]
47. Moore, E.A.; Russell, J.D.; Babbitt, C.W.; Tomaszewski, B.; Clark, S.S. Spatial modeling of a second-use strategy for electric vehicle batteries to improve disaster resilience and circular economy. *Resour. Conserv. Recycl.* **2020**, *160*, 104889. [CrossRef]
48. Ahuja, J.; Dawson, L.; Lee, R. A circular economy for electric vehicle batteries: Driving the change. *J. Prop. Plan. Environ. Law* **2020**, *12*, 235–250. [CrossRef]
49. Fan, E.; Li, L.; Wang, Z.; Lin, J.; Huang, Y.; Yao, Y.; Chen, R.; Wu, F. Sustainable Recycling Technology for Li-Ion Batteries and Beyond: Challenges and Future Prospects. *Chem. Rev.* **2020**, *120*, 7020–7063. [CrossRef]
50. Wu, H.; Hu, Y.; Yu, Y.; Huang, K.; Wang, L. The environmental footprint of electric vehicle battery packs during the production and use phases with different functional units. *Int. J. Life Cycle Assess.* **2020**, *26*, 97–113. [CrossRef]
51. Tang, Y.; Zhang, Q.; Li, Y.; Li, H.; Pan, X.; McLellan, B. The social-economic-environmental impacts of recycling retired EV batteries under reward-penalty mechanism. *Appl. Energy* **2019**, *251*, 113313. [CrossRef]
52. Arbabzadeh, M.; Lewis, G.M.; Keoleian, G.A. Green principles for responsible battery management in mobile applications. *J. Energy Storage* **2019**, *24*, 100779. [CrossRef]
53. Yang, Z.; Huang, H.; Lin, F. Sustainable Electric Vehicle Batteries for a Sustainable World: Perspectives on Battery Cathodes, Environment, Supply Chain, Manufacturing, Life Cycle, and Policy. *Adv. Energy Mater.* **2022**, *12*, 2200383. [CrossRef]
54. Stampatori, D.; Raimondi, P.P.; Noussan, M. Li-Ion Batteries: A Review of a Key Technology for Transport Decarbonization. *Energies* **2020**, *13*, 2638. [CrossRef]
55. Neumann, J.; Petranikova, M.; Meeus, M.; Gamarra, J.D.; Younesi, R.; Winter, M.; Nowak, S. Recycling of Lithium-Ion Batteries—Current State of the Art, Circular Economy, and Next Generation Recycling. *Adv. Energy Mater.* **2022**, *12*, 2102917. [CrossRef]
56. Lopez-Arboleda, E.; Sarmiento, A.T.; Cardenas, L.M. Systematic Review of Integrated Sustainable Transportation Models for Electric Passenger Vehicle Diffusion. *Sustainability* **2019**, *11*, 2513. [CrossRef]

57. Baars, J.; Domenech, T.; Bleischwitz, R.; Melin, H.E.; Heidrich, O. Circular economy strategies for electric vehicle batteries reduce reliance on raw materials. *Nat. Sustain.* **2020**, *4*, 71–79. [CrossRef]
58. Pinto, B.; Barata, F.; Soares, C.; Viveiros, C. Fleet Transition from Combustion to Electric Vehicles: A Case Study in a Portuguese Business Campus. *Energies* **2020**, *13*, 1267. [CrossRef]
59. Angnunavuri, P.N.; Kuranchie, F.A.; Attiogbe, F.; Nerquaye-Tetteh, E.N. The potential of integrating vehicular emissions policy into Ghana's transport policy for sustainable urban mobility. *SN Appl. Sci.* **2019**, *1*, 1201. [CrossRef]
60. Asekomeh, A.; Gershon, O.; Azubuike, S. Optimally Clocking the Low Carbon Energy Mile to Achieve the Sustainable Development Goals: Evidence from Dundee's Electric Vehicle Strategy. *Energies* **2021**, *14*, 842. [CrossRef]
61. Petrauskiene, K.; Dvarioniene, J.; Kaveckis, G.; Kliaugaite, D.; Chenadec, J.; Hehn, L.; Pérez, B.; Bordi, C.; Scavino, G.; Vignoli, A.; et al. Situation Analysis of Policies for Electric Mobility Development: Experience from Five European Regions. *Sustainability* **2020**, *12*, 2935. [CrossRef]
62. Onat, N.C.; Kucukvar, M. A systematic review on sustainability assessment of electric vehicles: Knowledge gaps and future perspectives. *Environ. Impact Assess. Rev.* **2022**, *97*, 106867. [CrossRef]
63. Zheng, X.; Lin, H.; Liu, Z.; Li, D.; Llopis-Albert, C.; Zeng, S. Manufacturing Decisions and Government Subsidies for Electric Vehicles in China: A Maximal Social Welfare Perspective. *Sustainability* **2018**, *10*, 672. [CrossRef]
64. Bhatti, G.; Mohan, H.; Singh, R.R. Towards the future of smart electric vehicles: Digital twin technology. *Renew. Sustain. Energy Rev.* **2021**, *141*, 110801. [CrossRef]
65. Petronijević, V.; Đorđević, A.; Stefanović, M.; Arsovski, S.; Krivokapić, Z.; Mišić, M. Energy Recovery through End-of-Life Vehicles Recycling in Developing Countries. *Sustainability* **2020**, *12*, 8764. [CrossRef]
66. Kurdve, M.; Zackrisson, M.; Johansson, M.I.; Ebin, B.; Harlin, U. Considerations when Modelling EV Battery Circularity Systems. *Batteries* **2019**, *5*, 40. [CrossRef]
67. Kannegiesser, M.; Günther, H.-O.; Gylfason, Ó. Sustainable development of global supply chains—Part 2: Investigation of the European automotive industry. *Flex. Serv. Manuf. J.* **2014**, *26*, 48–68. [CrossRef]
68. Onat, N.C.; Kucukvar, M.; Tatari, O. Towards Life Cycle Sustainability Assessment of Alternative Passenger Vehicles. *Sustainability* **2014**, *6*, 9305–9342. [CrossRef]
69. Syré, A.; Heining, F.; Göhlich, D. Method for a Multi-Vehicle, Simulation-Based Life Cycle Assessment and Application to Berlin's Motorized Individual Transport. *Sustainability* **2020**, *12*, 7302. [CrossRef]
70. Wang, Y.; Zhou, G.; Li, T.; Wei, X. Comprehensive Evaluation of the Sustainable Development of Battery Electric Vehicles in China. *Sustainability* **2019**, *11*, 5635. [CrossRef]
71. Reuter, B. Assessment of sustainability issues for the selection of materials and technologies during product design: A case study of lithium-ion batteries for electric vehicles. *Int. J. Interact. Des. Manuf. (IJIDeM)* **2016**, *10*, 217–227. [CrossRef]
72. Onat, N.C.; Kucukvar, M.; Tatari, O.; Egilmez, G. Integration of system dynamics approach toward deepening and broadening the life cycle sustainability assessment framework: A case for electric vehicles. *Int. J. Life Cycle Assess.* **2016**, *21*, 1009–1034. [CrossRef]
73. Pautasso, E.; Osella, M.; Caroleo, B. Addressing the Sustainability Issue in Smart Cities: A Comprehensive Model for Evaluating the Impacts of Electric Vehicle Diffusion. *Systems* **2019**, *7*, 29. [CrossRef]
74. Souza, L.L.P.D.; Lora, E.E.S.; Palacio, J.C.E.; Rocha, M.H.; Renó, M.L.G.; Venturini, O.J. Comparative environmental life cycle assessment of conventional vehicles with different fuel options, plug-in hybrid and electric vehicles for a sustainable transportation system in Brazil. *J. Clean. Prod.* **2018**, *203*, 444–468. [CrossRef]
75. Gradin, K.T.; Poulikidou, S.; Björklund, A.; Luttropp, C. Scrutinising the electric vehicle material backpack. *J. Clean. Prod.* **2018**, *172*, 1699–1710. [CrossRef]
76. Ellingsen, L.A.-W.; Hung, C.R.; Majeau-Bettez, G.; Singh, B.; Chen, Z.; Whittingham, M.S.; Strømman, A.H. Nanotechnology for environmentally sustainable electromobility. *Nat. Nanotechnol.* **2016**, *11*, 1039–1051. [CrossRef] [PubMed]
77. Tagliaferri, C.; Evangelisti, S.; Acconcia, F.; Domenech, T.; Ekins, P.; Barletta, D.; Lettieri, P. Life cycle assessment of future electric and hybrid vehicles: A cradle-to-grave systems engineering approach. *Chem. Eng. Res. Des.* **2016**, *112*, 298–309. [CrossRef]
78. Zeng, D.; Dong, Y.; Cao, H.; Li, Y.; Wang, J.; Li, Z.; Hauschild, M.Z. Are the electric vehicles more sustainable than the conventional ones? Influences of the assumptions and modeling approaches in the case of typical cars in China. *Resour. Conserv. Recycl.* **2020**, *167*, 105210. [CrossRef]
79. Picatoste, A.; Justel, D.; Mendoza, J.M.F. Circularity and life cycle environmental impact assessment of batteries for electric vehicles: Industrial challenges, best practices and research guidelines. *Renew. Sustain. Energy Rev.* **2022**, *169*, 112941. [CrossRef]
80. Mazur, C.; Contestabile, M.; Offer, G.J.; Brandon, N. Assessing and comparing German and UK transition policies for electric mobility. *Environ. Innov. Soc. Transit.* **2015**, *14*, 84–100. [CrossRef]
81. Gutiérrez, L.R.; Oliva, M.D.V.; Romero-Ania, A. Managing Sustainable Urban Public Transport Systems: An AHP Multicriteria Decision Model. *Sustainability* **2021**, *13*, 4614. [CrossRef]
82. Połom, M.; Wiśniewski, P. Implementing Electromobility in Public Transport in Poland in 1990–2020. A Review of Experiences and Evaluation of the Current Development Directions. *Sustainability* **2021**, *13*, 4009. [CrossRef]
83. Lindfors, A.; Ammenberg, J. Using national environmental objectives in green public procurement: Method development and application on transport procurement in Sweden. *J. Clean. Prod.* **2020**, *280*, 124821. [CrossRef]
84. Chen, J.; Wang, F.; He, X.; Liang, X.; Huang, J.; Zhang, S.; Wu, Y. Emission mitigation potential from coordinated charging schemes for future private electric vehicles. *Appl. Energy* **2021**, *308*, 118385. [CrossRef]

85. He, Z.; Zhou, Y.; Wang, J.; Li, C.; Wang, M.; Li, W. The impact of motivation, intention, and contextual factors on green purchasing behavior: New energy vehicles as an example. *Bus. Strat. Environ.* **2020**, *30*, 1249–1269. [CrossRef]
86. Asadi, S.; Nilashi, M.; Samad, S.; Abdullah, R.; Mahmoud, M.; Alkinani, M.H.; Yadegaridehkordi, E. Factors impacting consumers' intention toward adoption of electric vehicles in Malaysia. *J. Clean. Prod.* **2020**, *282*, 124474. [CrossRef]
87. Tu, J.-C.; Yang, C. Key Factors Influencing Consumers' Purchase of Electric Vehicles. *Sustainability* **2019**, *11*, 3863. [CrossRef]
88. Skrúcaný, T.; Kendra, M.; Stopka, O.; Milojević, S.; Figlus, T.; Csiszár, C. Impact of the Electric Mobility Implementation on the Greenhouse Gases Production in Central European Countries. *Sustainability* **2019**, *11*, 4948. [CrossRef]
89. Zhang, Z.; Sun, X.; Ding, N.; Yang, J. Life cycle environmental assessment of charging infrastructure for electric vehicles in China. *J. Clean. Prod.* **2019**, *227*, 932–941. [CrossRef]
90. Mitropoulos, L.K.; Prevedouros, P.D. Life cycle emissions and cost model for urban light duty vehicles. *Transp. Res. Part D Transp. Environ.* **2015**, *41*, 147–159. [CrossRef]
91. Hache, E.; Seck, G.S.; Simoen, M.; Bonnet, C.; Carcanague, S. Critical raw materials and transportation sector electrification: A detailed bottom-up analysis in world transport. *Appl. Energy* **2019**, *240*, 6–25. [CrossRef]
92. Sen, B.; Onat, N.C.; Kucukvar, M.; Tatari, O. Material footprint of electric vehicles: A multiregional life cycle assessment. *J. Clean. Prod.* **2018**, *209*, 1033–1043. [CrossRef]
93. Richa, K.; Babbitt, C.W.; Gaustad, G. Eco-Efficiency Analysis of a Lithium-Ion Battery Waste Hierarchy Inspired by Circular Economy. *J. Ind. Ecol.* **2017**, *21*, 715–730. [CrossRef]
94. Hao, H.; Liu, Z.; Zhao, F.; Geng, Y.; Sarkis, J. Material flow analysis of lithium in China. *Resour. Policy* **2016**, *51*, 100–106. [CrossRef]
95. Vidhi, R.; Shrivastava, P. A Review of Electric Vehicle Lifecycle Emissions and Policy Recommendations to Increase EV Penetration in India. *Energies* **2018**, *11*, 483. [CrossRef]
96. Watari, T.; Nansai, K.; Nakajima, K.; McLellan, B.C.; Dominish, E.; Giurco, D. Integrating Circular Economy Strategies with Low-Carbon Scenarios: Lithium Use in Electric Vehicles. *Environ. Sci. Technol.* **2019**, *53*, 11657–11665. [CrossRef] [PubMed]
97. López, I.; Ibarra, E.; Matallana, A.; Andreu, J.; Kortabarria, I. Next generation electric drives for HEV/EV propulsion systems: Technology, trends and challenges. *Renew. Sustain. Energy Rev.* **2019**, *114*, 109336. [CrossRef]
98. Spreafico, C. Can modified components make cars greener? A life cycle assessment. *J. Clean. Prod.* **2021**, *307*, 127190. [CrossRef]
99. Ohno, H.; Matsubae, K.; Nakajima, K.; Kondo, Y.; Nakamura, S.; Fukushima, Y.; Nagasaka, T. Optimal Recycling of Steel Scrap and Alloying Elements: Input-Output based Linear Programming Method with Its Application to End-of-Life Vehicles in Japan. *Environ. Sci. Technol.* **2017**, *51*, 13086–13094. [CrossRef]
100. He, X.; Su, D.; Cai, W.; Pehlken, A.; Zhang, G.; Wang, A.; Xiao, J. Influence of Material Selection and Product Design on Automotive Vehicle Recyclability. *Sustainability* **2021**, *13*, 3407. [CrossRef]
101. Pamucar, D.; Deveci, M.; Gokasar, I.; Işık, M.; Zizovic, M. Circular economy concepts in urban mobility alternatives using integrated DIBR method and fuzzy Dombi CoCoSo model. *J. Clean. Prod.* **2021**, *323*, 129096. [CrossRef]
102. Fishman, T.; Heeren, N.; Pauliuk, S.; Berrill, P.; Tu, Q.; Wolfram, P.; Hertwich, E.G. A comprehensive set of global scenarios of housing, mobility, and material efficiency for material cycles and energy systems modeling. *J. Ind. Ecol.* **2021**, *25*, 305–320. [CrossRef]
103. Pomili, L.; Fabrizi, A. automotive recycling: A circular economy centre. *Environ. Eng. Manag. J.* **2020**, *19*, 1747–1753. [CrossRef]
104. Tan, J.; Wehde, M.V.; Brønd, F.; Kalvig, P. Traded metal scrap, traded alloying elements: A case study of Denmark and implications for circular economy. *Resour. Conserv. Recycl.* **2020**, *168*, 105242. [CrossRef]
105. Islam, T.; Iyer-Raniga, U.; Trewick, S. Recycling Perspectives of Circular Business Models: A Review. *Recycling* **2022**, *7*, 79. [CrossRef]
106. Haupt, M.; Vadenbo, C.; Hellweg, S. Do We Have the Right Performance Indicators for the Circular Economy?: Insight into the Swiss Waste Management System. *J. Ind. Ecol.* **2016**, *21*, 615–627. [CrossRef]
107. Parchomenko, A.; Nelen, D.; Gillabel, J.; Vrancken, K.C.; Rechberger, H. Evaluation of the resource effectiveness of circular economy strategies through multilevel Statistical Entropy Analysis. *Resour. Conserv. Recycl.* **2020**, *161*, 104925. [CrossRef]
108. Onat, N.C.; Aboushaqrah, N.N.; Kucukvar, M.; Tarlochan, F.; Hamouda, A.M. From sustainability assessment to sustainability management for policy development: The case for electric vehicles. *Energy Convers. Manag.* **2020**, *216*, 112937. [CrossRef]
109. Onat, N.C.; Kucukvar, M.; Aboushaqrah, N.N.; Jabbar, R. How sustainable is electric mobility? A comprehensive sustainability assessment approach for the case of Qatar. *Appl. Energy* **2019**, *250*, 461–477. [CrossRef]
110. Ortego, A.; Valero, A.; Valero, A.; Iglesias, M. Downcycling in automobile recycling process: A thermodynamic assessment. *Resour. Conserv. Recycl.* **2018**, *136*, 24–32. [CrossRef]
111. Diener, D.L.; Tillman, A.-M. Scrapping steel components for recycling—Isn't that good enough? Seeking improvements in automotive component end-of-life. *Resour. Conserv. Recycl.* **2016**, *110*, 48–60. [CrossRef]
112. Chen, Z.; Chen, D.; Wang, T.; Hu, S. Policies on end-of-life passenger cars in China: Dynamic modeling and cost-benefit analysis. *J. Clean. Prod.* **2015**, *108*, 1140–1148. [CrossRef]
113. Karagoz, S.; Aydin, N.; Simic, V. End-of-life vehicle management: A comprehensive review. *J. Mater. Cycles Waste Manag.* **2019**, *22*, 416–442. [CrossRef]
114. Saidani, M.; Yannou, B.; Leroy, Y.; Cluzel, F. Dismantling, remanufacturing and recovering heavy vehicles in a circular economy—Technico-economic and organisational lessons learnt from an industrial pilot study. *Resour. Conserv. Recycl.* **2020**, *156*, 104684. [CrossRef]

115. Lee, C.-K.; Lee, J.-Y.; Kim, J. Recyclability and Recoverability of Rolling Stock with Recycling Efficiency Factors. *Resour. Conserv. Recycl.* **2020**, *155*, 104620. [CrossRef]
116. Esteva, L.C.A.; Kasliwal, A.; Kinzler, M.S.; Kim, H.C.; Keoleian, G.A. Circular economy framework for automobiles: Closing energy and material loops. *J. Ind. Ecol.* **2020**, *25*, 877–889. [CrossRef]
117. Bastida-Molina, P.; Hurtado-Pérez, E.; Peñalvo-López, E.; Gómez, M.C.M. Assessing transport emissions reduction while increasing electric vehicles and renewable generation levels. *Transp. Res. Part D Transp. Environ.* **2020**, *88*, 102560. [CrossRef]