How do firms interpret extended responsibilities for a sustainable supply chain management of innovative technologies? An analysis of corporate sustainability reports in the energy sector

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Abstract

Purpose of the paper: *This paper aims to analyze how companies fulfill their responsibility in shaping sustainable supply chain strategies for innovative technologies. To this end, it describes a decade of evolution of Lithium-ion batteries (LIBs) end-of-life management practices among leading energy utilities.*

Methodology*: Using GRI's Sustainability Disclosure Database, a content analysis of 172 corporate sustainability reports of 16 European energy utilities was conducted.*

Results*: The content analysis provides a clear idea of the actual commitment to foster LIBs end-of-life management by highlighting that energy utilities are still far from taking lead responsibilities on this emerging -yet potentially critical- issue. Apart from minor initiatives, LIBs are crucial for building short-term business strategies that, however, overlook their relevance for the implementation of the extended producer responsibility principle.*

Research limits: *The main limitations are the use of publicly accessible web sites and corporate sustainability reports, which are concise and secondary data sources, and the lack of comparison of energy utilities with sustainability leaders from other industries.*

Practical implications: *The study helps managers to more fully comprehend environmental issues associated with emerging and soon to be widespread products and, thus, to better focus on the opportunities and problems of end-of-life management for innovative technologies.*

Originality of the paper: *The study is unique in its purpose to complement publicly accessible information from the Internet with sustainability reports to provide a systemic view on how crucial actors within the supply chain of innovative technologies implement specific environmental practices that might affect the future of these technologies.*

Key words: end-of-life; extended responsibility; supply chain management; sustainability report

1. Introduction

The implementation of comprehensive environmental strategies and disclosure in the context of supply chain management has become a crucial issue for companies (Beske and Seuring, 2014). Companies are increasingly asked by stakeholders and consumers to improve their environmental performance. For this reason, companies must understand and decide how to tackle sustainable challenges in supply chain management, which has a broad influence on many issues, including: product innovation, organizational structures, and relationships with customers and stakeholders (Neutzling *et al.*, 2018).

Comas Martì and Seifert (2013) note that suitable environmental strategies require the implementation of a comprehensive environmental management system encompassing a clear identification of relevant environmental aspects, their location in the supply chain or product life cycle, and the mobilization of adequate resources. According to this framework, each company in the supply chain is free to tackle sustainable challenges and to disclose related information with different levels of commitment (Meckenstock *et al.*, 2016), which poses additional challenges when environmental performance is highly interdependent.

In this framework, the scientific literature provides some insights on how sustainability principles can be turned into operational practices across the supply chain and to what extent they ensure the sound management of environmental issues beyond corporate regulatory compliance (Comas Martì and Seifert, 2013; Meckenstock *et al.*, 2016). The increasing interest in the link between internal environmental practices and environmental practices at the supply chain level (Zhu *et al.*, 2012; Graham, 2018) is, in particular, shedding light on why and how companies should consider and assume their role in end-of-life management from an extended producer responsibility perspective (Toffel, 2003; Hickle, 2017). In fact, the implementation of end-of-life management practices is a controversial feature of sustainability along the supply chain. Some companies consider them as cost to be minimized, whereas others are actively engaged in the development and implementation of end-of-life management practices to achieve strategic opportunities (Pagell *et al.*, 2007).

Studies on end-of-life management often analyze the implementation of win-win solutions ranging from waste collection and material recovery to reuse, refurbishment and remanufacturing, as well as cooperation among relevant stakeholders in the product life-cycle and product design (Atlason *et al.*, 2017). However, although these studies offer a clear rationale for the business case of sustainability in the short run, they often overlook the investigation of corporate strategies and associated partnerships aimed at affecting of more systemic changes in the supply chain (Stewart and Niero, 2018). As a consequence, little is known on how core actors along the supply chain can support or, moreover, lead the coordination of efforts to manage big environmental issues that seem to fall above of the corporate agenda.

In this paper we investigate how energy utilities are making their part in building a sustainable Lithium-ion batteries (LIBs) end-of-life management moving beyond the predominance of retailer-manufacturer research and providing more insights on the role of core actors in the supply chain according to the collaborative paradigm. We aim to develop a better understanding of LIBs end-of-life management practices and collaborative relationships implemented by energy utilities to integrate sustainability into LIBs supply chain.

The contribution of this study is threefold. First, we contribute to the sustainable supply chain literature by exploring the role of core actors along the supply chain and their collaborations to tackle the controversial role of product end-of-life management in an emerging supply chain (Pagell *et al.*, 2007). Second, we integrate the analysis of sustainability reporting by investigating supply chain dynamics (Wijk and Persoon, 2006). Third, we provide empirical evidence of the state-of-the-art of LIBs end-of-life management practices (Mayyas *et al.*, 2019).

In particular, we analyze what 16 leading European energy utilities disclose about their environmental practices and strategies through corporate sustainability reports, which constitute an effective source of information to investigate companies' commitment to sustainability and associated practices (Comas Martì and Seifert, 2013; Meckenstock *et al.*, 2016; Stewart and Niero, 2018). In fact, sustainable reports, complemented by supplementary data, can show the level of priority that companies assigned to activities to tackle sustainable development challenges (Hickle, 2017). A content analysis on the collected evidence from sustainability reports and supplementary data (i.e. company websites and online press releases) is thus used to explore product end-of-life management activities and their effects on the evolution of the supply chain.

The remainder of the article is structured as follows. In section 2, we provide the theoretical background on the integration of product end-of-life management practices into sustainable supply chain management, and sustainable disclosure of supply chain strategies from which we derive the research questions. In section 3, we introduce the methods used to address our research questions, after which, in section 4, we present the results from the analysis of the corporate sustainability reports. Finally, we discuss the main evidence and conclude by shedding light on the limitations of the present study and providing the theoretical and managerial implications of the results.

2. Theoretical background

2.1 Sustainable supply chain management and the challenges of product end-of-life management

Several scholars highlight the integrative framework that sustainable supply chain management provides, which informs a broad range of decisions affecting the product life cycle (Gupta and Palsule-Desai, 2011). In fact, companies that adopt a sustainable supply chain management approach often tend to consider and address stakeholders' pressure to reduce their environmental and, increasingly, social impacts and other potential risks (Neutzling *et al.*, 2018; van Bommel, 2011), which often lead to the implementation of comprehensive strategies to improve their environmental, social and economic performance (Carter and Rogers, 2008).

Considering that sustainable supply chain management encompasses several activities ranging from products to process-related innovations

(Hickle, 2017; Neutzling *et al.*, 2018), companies can assume different approaches for the translation of sustainability principles into operational practices, as well as different levels of comprehensiveness of environmental strategies within the supply chain (Comas Martì and Seifert, 2013; Meckenstock *et al.*, 2016). Aligning internal environmental practices and the promotion of environmental practices at supply chain level is thus a complex task that requires a good understanding of corporate and systemic dynamics, given that a company cannot be considered without its business environment (Zhu *et al.*, 2012; Graham, 2018). Monitoring the evolution of the relationships between actors throughout the value chain might help to understand the problems and opportunities posed by end-of-life management activities, including those hidden behind waste collection, material recovery, reuse, refurbishment and remanufacturing, as well as the potential for cooperation among key stakeholders in the product life-cycle and product design (Toffel, 2003; Hickle, 2017; Atlason *et al.*, 2017).

Scouting business threats and opportunities related to end-of-life management can help companies to take a responsible approach to supply chain management. This does not just mean implementing closed-loop supply chains, but also extending the boundary of the analysis of possible direct and indirect impacts of corporate strategies (Defee *et al.*, 2009). Moreover, companies can be more agile in responding to uncertainties and complexities associated with the supply chain (Prater *et al.*, 2001), given that they can implement solutions and practices fostering flexibility and innovation to achieve a sustainable supply chain (Ciccullo *et al.*, 2018).

Whatever the influence exerted on the supply chain might be, it requires cooperation with relevant stakeholders involved in the product design (Atlason *et al.*, 2017) and in the product life-cycle (including producers and consumers/end users) (Hickle, 2017). Nonetheless, some studies highlight the importance of collaborative relationships between companies and their business ecosystem or of initiatives with consumers/users in the implementation of sustainability paradigm (Vachon and Klassen, 2006; Formentini and Taticchi, 2016). The analysis of corporate strategies for product end-of-life management and of the related strong collaborations (i.e. partnerships) aimed at affecting a systemic change in terms of the reconfiguration of resources and capabilities among supply chain members is still needed (Stewart and Niero, 2018), thus leading us to our first direction of investigation:

1) Given the increasing awareness on sustainability challenges in the LIBs industry, do energy utilities develop end-of-life management strategies to take a proactive approach to sustainability and develop systemic changes at the supply chain level?

2.2 The use of sustainability reports in spreading awareness on sustainability issues at the supply chain level

Corporate sustainability reports have increasingly become an effective way to provide information on corporate strategies and activities towards sustainability (Comas Martì and Seifert, 2013; Meckenstock *et al.*, 2016; Stewart and Niero, 2018).

The voluntary nature of these instruments allows for some degrees of freedom in defining the content and level of disclosure of corporate sustainability (Meckenstock *et al.*, 2016). Therefore, sustainability reports inform researchers on both how companies report their engagement in sustainability in specific areas and whether they ignore others.

Wijk and Persoon (2006) highlight the potential for researchers to investigate supply chain dynamics on sustainability reports. The analysis of sustainability reports can focus on how a single company shapes sustainability practices and performance of their partners along the supply chain (Tate *et al.*, 2010) or on how companies that are responsible for different phases of the product life cycle (e.g. upstream, midstream and downstream) pursue synergies along the whole supply chain (Halldórsson *et al.*, 2009). The coexistence of these two perspectives characterizes the corporate sustainability reporting of those companies that have a crucial role in sustainable supply chain management, since they can both foster the dissemination of internal environmental practices and absorb external scientific and technological capabilities from partners throughout the supply chain. Considering that Meckenstock *et al.* (2016) show that pressures toward sustainability are typically stronger in the downstream supply chain, where companies have closer relations with stakeholders and in particular with consumers, the selection of the supply chain phase to be investigated is thus relevant for accessing valuable information about the systemic changes underway in the supply chain for integrating sustainability. End-of-life management activities typically involve more downstream companies with a high potential of cooperation with an open network of incumbents and new entrants of a sustainable value chain also in open loop-supply chains (Atlason *et al.*, 2017; Rizzi *et al.*, 2014), which leads to our second direction of investigation:

2) When pursuing systemic changes at the supply chain level, is there a prevailing attention among energy utilities towards the coordination of internal or external resources?

Taking a comprehensive approach, by focusing on an evolutionary perspective of supply chain management practices, this study aims to answer the following research questions:

RQ1: How is end-of-life management of LIBs practices and related partnerships evolved according to corporate sustainability reports of downstream companies?

RQ2: Which internal and external dynamics associated with end-of-life management practices and related partnerships in downstream companies have led to systemic changes of the LIBs supply chain?

3. Methods

3.1 Research context

LIBs are a rapidly evolving technology constantly gaining market shares because of their high technical performance in electric mobility and energy storage, i.e. high energy and power density, low weight, and long life. In fact, the global LIBs market reached $29.86 billion in 2017 and is expected to skyrocket to $139.36 billion by 2026 - a growth rate of 18.7% (Stratistics Market Research Consulting, 2018). However, LIBs still have uncertain value chains after their use and rapid depreciation.

The growing demand for this technology, often boosted by anticipated substitutions for staying aligned with the-state-of-the-art standards of performance, generates the rise of prices for raw materials and negative environmental impacts primarily associated with the mining activities for supplying rare and scarce materials and disposal of spent LIBs and their hazardous materials in landfills, which are far away from market users but might facilitate the development of alternatives technologies (Mayyas *et al.*, 2019). Therefore, LIBs end-of-life management, including recycling, has become an environmental -not yet industrial- priority that is challenging all the various actors involved in the supply chain and different energy storage-based business models. Among these actors, energy utilities, which are increasingly using LIBs for network stabilization and for the integration into the grid of renewable -and by nature non-programmable- energy sources, play a key role in shifting the LIBs supply chain towards sustainability (Lebedeva *et al.*, 2017).

3.2 Sample definition

The sample of companies included in this study was compiled using GRI's Sustainability Disclosure Database[1]. This database includes thousands of reports published from 1999 until present, the majority of which (around 65%) are based on GRI guidelines or standards and the remaining (around 35%) of which comprise reports, including sustainability disclosures.

We analyzed corporate sustainability reports of European energy utilities, because the increasing use of LIBs in energy storage for network stabilization and for the integration of renewable energy sources in the energy system poses relevant environmental challenges to the energy industry as a whole (Lebedeva *et al.*, 2017). It is worth noting that the European Union considers the development, production, use and end-of-life management of batteries, especially LIBs, a priority also for the automotive industry (Science for Environment Policy, 2018; Tutore *et al.*, 2014).

In order to determine the key players that might influence the development of end-of-life management of LIBs, we identified 124 European energy utilities in GRI's Sustainability Disclosure Database. However, we selected sustainability reports of only those European energy utilities that explicitly reported actions related to "batteries" or/and "storage" between 2006 and 2016.

After this selection, the final sample contains 172 corporate sustainability reports from a little bit more than a decade of disclosures of 16 European energy utilities. Table 1 provides the list of analyzed companies and some descriptive information.

[1] The GRI's Sustainability Disclosure Database is constantly changing because some companies add or remove certain reports. The selection of reports to be used in this study was made between July 5th and 10th, 2018.

Tab. 1: List of analyzed energy utilities and some descriptive information

Company	Country	Number of employees (2018)	Turnover (2018), thousands USD
ACEA	Italy	656	3,467,618
EDP (Energias de Portugal)	Portugal	11,631	18,137,682
EnBW	Germany	21,524	24,216,533
Endesa	Spain	9,763	23,123,287
Enel	Italy	69,272	86,246,023
E.ON	Germany	43,302	35,648,448
HERA	Italy	8,622	7,587,232
Iberdrola	Spain	28,750	40,919,828
Naturgy Energy Group S.A	Spain	12,700	28,058,239
Orsted Energy A/S	Denmark	6,080	11,778,998
Red Eléctrica de España S.A	Spain	1,799	2,245,616
REN (Redes Energéticas Nacionais)	Portugal	692	826,029
Snam S.p.A	Italy	3,016	2,960,971
Statkraft A.S	Norway	3,229	6,471,001
Terna S.p.A.	Italy	4,252	2,653,997
Vattenfall	Sweden	19,910	17,613,385

Source: Authors' elaboration from ORBIS database

3.3 Content analysis

Content analysis consisted of a systematic categorization of the collected data (Hsieh and Shannon, 2005). We first grouped information from raw data by relevant recurring themes and then coded the textual content of sustainability reports according to our research framework by using NVivo software 2011.

Then, we carried out qualitative and inductive analysis of the content of sustainability reports (Thomas, 2006). Initially, we identified how selected energy utilities addressed and integrated the concept of energy storage into their sustainable strategy and related initiatives. This phase of the analysis was supported by supplementary information collected from company websites and online press releases. Then, we referred to two key themes (end-of-life management activities and related partnerships) for exploring the ten-year evolution of sustainable practices throughout the LIBs supply chain. These themes were subsequently further developed and adapted according to the ideas emerging from the data analysis. At the end of this inductive process, we formed 27 categories grouped under three broad themes and seven sub-themes. In total, we coded 926 excerpts from the reports. For both key themes (product end-of-life management activities and related partnerships for LIBs addressed in this study), we used segments derived from 14 categories, grouped into three sub-themes: short-term orientation in planning for the use and replacement of LIBs, volatility of partnership in sustainability-oriented projects and lack of end-of-life perspective in designing a sustainable supply chain management. To ensure the accuracy of the analysis, we employed two verification strategies. First, the interpretation of information contained in the sustainability reports was supported by the definition of the categories (Miles and Huberman, 1994). Accordingly, these definitions allowed the standardization of the codification process. New categories were discussed by researchers involved in the process during two meetings. Second, the first coded reports helped the evaluation of clarity of categories in order to achieve a common understanding of the coding tree (Thomas, 2006). A double-blind coding was carried out for the first 15 reports to compare categories created by the two researchers. At the end of this phase, we merged some categories. This analysis highlighted the different companies' interpretation of end-of-life management practices for LIBs.

4. Results

The analysis of product end-of-life management activities and related partnerships for LIBs in sustainability reports reveals that, even though several companies mention their interest in energy storage as solution for the development of effective smart grids and the integration of renewable energy sources into grids, but also for fostering recharge infrastructures for electrical vehicles (e.g. charging columns and other innovative solutions), few of the analyzed energy utilities have already committed to end-of-life management of LIBs and related evolution of supply chain along ten years. In particular, sustainability reports emphasize associated benefits in terms of network stabilization and reduction of CO2 emission. Therefore, companies highlight their involvement in the technology development of energy storage through pilot projects for boosting the adoption of LIBs at large scale. Companies often carry out more than one pilot project in order to test different fields of application (micro-grids, electrical mobility, etc.). Table 2 summarizes the pilot projects implemented by the analyzed energy utilities.

Overall, the collected evidence can be clustered into three interdependent topics that characterize the possible evolution of LIBs supply chain towards sustainability:

- a short-term orientation in planning for the use and replacement of LIBs;
- the volatility of partnerships in sustainability-oriented projects;
- the lack of end-of-life perspective in designing a sustainable supply chain management.

4.1 Short-term orientation in planning for the use and replacement of LIBs

The commitment to the development and diffusion of LIBs has not compelled most analyzed companies to plan and adopt LIBs end-of-life practices. In fact, only three companies (Endesa, Enel and Vattenfall) disclose the implementation of actions to address LIBs end-of-life issues in their sustainability reports. In particular, Endesa, Enel and Vattenfall have promoted initiatives and programs for second life applications suitable for re-using LIBs from electric vehicles (Table 3). In fact, these companies tried to find and test other applications for LIBs from electric vehicles that have lost 75-80% of their initial capacity in stationary energy storage. Vattenfall has worked to re-use LIBs from electric vehicles as an energy storage for the integration of renewable energy sources into grids since 2013. Endesa declared initiatives for promoting the second life of LIBs in 2015. Even though Enel has made the effort to recycle and recover lead batteries since 2006, the company has implemented the first initiative for fostering second life of LIBs only since 2017.

These results confirm the difficulty of companies to implement and accordingly report end-of-life management practices (Stewart and Niero, 2019). One solution is to implement second life initiatives for addressing some of the short-term challenges related to a sustainable LIBs supply chain because this option can postpone some critical issues associated with LIBs end-of-life management (e.g. the lack of viable collection mechanism for spent batteries and low volume and high costs of LIBs recycling) (Mayyas *et al.*, 2019). Moreover, LIBs end-of-life practices are not yet considered as a priority by most energy utilities that place less emphasis on their role for achieving sustainability within the LIBs supply chain. This attitude may be explained by their downstream position along LIBs supply chain and not their direct linkage with LIBs manufacturing. In fact, Meckenstock *et al.* (2016) argue that companies belonging to midstream or downstream supply chain echelons can have different attitude in the integration of sustainability practice into supply chain.

Tab. 2: Pilots projects for boosting energy storage and electric vehicles, and batteries end-of-life practices mentioned in corporate sustainability reports

	Pilot projects		
Company	Energy Storage for Smart grid	Energy Storage for Renewables	Diffusion of Electric vehicles
ACEA	-		-
EDP (Energias de Portugal)	-	-	-
EnBW	-		-
Endesa	-		-
Enel	-	-	-
E.ON		-	-
HERA		-	
Iberdrola		-	-
Naturgy Energy Group S.A	-		-
Orsted Energy A/S		-	-
Red Eléctrica de España S.A		-	-
REN (Redes Energéticas Nacionais)	-		-
Snam S.p.A		-	
Statkraft A.S		-	
Terna S.p.A.	-	-	
Vattenfall		-	-
Total	8	11	12

Source: Authors' elaboration

Tab. 3: LIBs and generic batteries end-of-life practices mentioned in corporate sustainability reports

Company	LIBs end-of-life practices	Generic batteries end-of-life practices
ACEA		
EDP (Energias de Portugal)		
EnBW		
Endesa	-	
Enel	-	
E.ON		
HERA		-
Iberdrola		-
Naturgy Energy Group S.A		-
Orsted Energy A/S		
Red Eléctrica de España S.A		-
REN (Redes Energéticas Nacionais)		
Snam S.p.A		-
Statkraft A.S		
Terna S.p.A.		-
Vattenfall	-	
Total	3	6

Source: Authors' elaboration

4.2 Volatility of partnership in sustainability-oriented projects

The majority of analyzed companies report some collaborations and partnerships for the diffusion of electric vehicles, the development of energy storage, but rarely for LIBs end-of-life management (Table 4). Companies describe these partnerships by highlighting associated benefits mainly in terms of research and technology development projects. However, the network of partners is highly heterogeneous and volatile.

Six companies (EnBW, Endesa, Enel, Orsted, REN and Vattenfall) mention partnerships for fostering electric mobility through the development of fast and smart recharge systems and electric vehicles as movable energy storage from renewable sources. In particular, companies have mainly established partnerships with car manufacturers: Daimler (EnBW); Renault, Nissan, Mitsubishi, Peugeot and Toyota (Endesa); Smart, Nissan and BYD (Enel); Volvo, Mitsubishi and Scania AB (Vattenfall). Car manufactures support energy utilities by providing electric vehicles for pilot projects and then increase the visibility of their models or prototypes. Orsted declared a past partnership with BetterPlace, company that developed and sold battery-charging and battery-switching services for electric cars.

Other partnerships involve research centers and universities in order to experiment innovative solutions for recharging electric vehicles: University of Zaragoza and Research Centre on Energy Resources and Consumption (Endesa); INESC TEC - Institute for Systems and Computer Engineering, Technology and Science (REN); KTH - Royal Institute of Technology in Stockholm (Vattenfall).

Tab. 4: Partnerships for electric mobility, energy storage and LIBs end-of-life management mentioned in corporate sustainability reports

Company	Partnership for electric mobility	Partnership for energy storage	Partnership for LIBs end-of-life management
ACEA		-	
EDP (Energias de Portugal)			
EnBW	-		
Endesa	-	-	-
Enel	-	-	-
E.ON			
HERA			
Iberdrola			
Naturgy Energy Group S.A		-	
Orsted Energy A/S	-		
Red Eléctrica de España S.A		-	
REN (Redes Energéticas Nacionais)	-		
Snam S.p.A			
Statkraft A.S			
Terna S.p.A.		-	
Vattenfall	-		
Total	6	6	2

Source: Authors' elaboration

Acea, Endesa, Enel, Naturgy, Red and Terna mention partnerships with companies, international associations and research teams for acquiring and increasing knowledge and expertise in energy storage systems. Naturgy, Red and Terna are members of the European Association for Storage of Energy, which promotes the development of innovative and cost-effective technologies for energy storage.

Other energy utilities have partnerships with information technology companies and universities able to provide suitable software, networks and platform for developing effective energy storage systems: NEC (Acea); CapGemini, Polytechnic Universities of Madrid and Malaga (Endesa); Tesla (Enel); Joint Spanish Platforms for Energy Storage (Naturgy).

Only two companies (Endesa and Enel) have already established partnerships for addressing LIBs end-of-life management. In particular, Endesa signed an agreement with Enel for carrying out the "Green eMotion" project on the second life of electric vehicle batteries in 2015. Enel has established a partnership with the Italian non-profit private Consortium COBAT[2] for promoting effective batteries end-of-life practices in terms of second life applications, collection and recycling of batteries, and particularly LIBs. However, the analysis of sustainability reports does not highlight the implementation of partnerships between energy utilities and LIBs recycling companies (e.g. Umicore).

2 COBAT promotes and arranges all the necessary activities for the correct management and disposal of the waste electrical and electronic, batteries, solar panels and tires. For more details, see: https://www.cobat.it/

These results evidence that partnerships are a competitive advantage action for fostering the exchange of information and knowledge between the analyzed energy companies and potential partners of associated supply chains (i.e. energy storage and electric vehicles) (Vachon and Klassen, 2006). Moreover, they prefer to focus on technological innovation aspects by ignoring consumer-based research and design (Stewart and Niero, 2018). The strong interest in technological aspects results from the initial diffusion of energy storage systems and electric vehicles and the understanding of their great potential for development in the near future.

The scarcity of disclosure concerning the existence of partnerships for addressing LIBs end-of-life management issues confirms a weak long-term orientation in terms of sustainability within the overall supply chain. Moreover, this result highlights that all analyzed energy utilities, except for Endesa and Enel, have not yet felt the urgency of a partnership for LIBs end-of-life management practices. Therefore, energy utilities lose the chance to build long-term relationships with partners by increasing trust and removing uncertainties within a sustainable supply chain. A possible reason of this lack of partnerships can be supply chain echelons where companies operate and then the distance from LIBs producers (Meckenstock *et al.*, 2016). Thus, it becomes crucial that energy utilities understand their potential role played within LIBs supply chain for addressing sustainability and particularly end-of-life issues.

4.3 Lack of end-of-life perspective in designing a sustainable supply chain management

Companies do not mention any specific long-term strategy associated with LIBs end-of-life management and furthermore sustainability issues within LIBs supply chain in their sustainability reports. As already discussed, most energy utilities do not even report isolated initiatives or projects for promoting LIBs end-of-life management.

However, among the few, Endesa, Enel and Vattenfall have implemented and reported initiatives for the second life of LIBs, although companies do not describe if these initiatives have already generated benefits in terms of the integration of effective end-of-life practices within LIBs supply chain. The sustainability reports of these three energy utilities do not indicate the evolution of mentioned initiatives toward an integration of end-of-life management into LIBs supply chain in terms of material recovery to reuse, refurbishment and remanufacturing, and a stable cooperation among pivotal stakeholders in the product life-cycle and product design.

Overall, clear evidence emerges of the lack of an actual commitment of energy utilities towards LIBs end-of-life management and of the fact that these companies do not yet consider environmental issues associated with the emerging and soon to be widespread application of LIBs as a priority to be tackled through proactive environmental practices at supply chain level.

The lack of diffused and detailed disclosure of LIBs end-of-life management practices according to a systemic perspective shows that much remains to be done in terms of integration of LIBs end-of-life management strategies and systemic changes into the supply chain. On the one hand, as Comas Martì and Seifert (2013) argue, the untapped potential for improvement in terms of comprehensiveness of LIBs end-of-life management practices and strategies might be linked to the relevance of stakeholder pressures within LIBs supply chain. On the other hand, it might be linked also to an informed negligence of this industry towards a clear participation in building a resilient supply chain from an extended producer responsibility perspective.

5. Discussion and conclusions

In the absence of sound and sustainable material recovery processes, the LIBs supply chain has the typical open-loop structure, with producers that invest in product innovation without prioritizing take-back options, key users urged to implement upstream and downstream sustainable procurement strategies and a variety of end-of-life management companies performing some trial and error search for the more sustainable solutions. Therefore, our explorative study, which covers a ten-year evolution of sustainable supply chain management strategies in energy utilities, focuses on decision makers that are pivotal for the development of industrial partnerships and, thus, central for understanding the dynamics in terms of reconfigurations of resources and capabilities among supply chain members that characterize the early structuration of practices for addressing LIBs end-of-life management.

This study contributes to the sustainable supply chain literature by exploring the role of core actors along the supply chain (i.e. energy utilities) and related collaborations in the implementation of product end-of-life management by considering its controversial nature in an emerging supply chain (Pagell *et al.*, 2007). Second, the analysis of sustainability reports shows all actions and collaborations that demonstrate the integration of the tenets of sustainability into the supply chain (Wijk and Persoon, 2006). Moreover, the content analysis of 172 sustainability reports published between 2006 and 2016 by the 16 European energy utilities, which disclosed a tangible commitment to reduce LIBs environmental externalities, highlights both opportunities and threats for the long term development of a LIBs sustainable supply chain.

Surprisingly, despite the awareness on the strategic importance of the topic, only 3 energy utilities over 124 report some initiatives and projects on LIBs end-of-life management. The resulting network of collaborations for promoting LIBs end-of-life management is fragmented and volatile, with a prevailing focus on the reuse of second-life of LIBs in electric vehicles. Furthermore, material recovery still seems to be an undeveloped option, and the pace of introduction of end-of-life solutions is by far slower than the introduction of user-oriented improvements. This evidences that LIBs end-of-life management is still not considered as a strategic opportunities by the majority of core actors within the supply chain (Pagell *et al.*, 2007),

Even though LIBs performances are improving at a pace that is imposing premature substitutions and shorter life cycles, which are both environmentally and financially relevant for designing corporate strategies, the 16 energy utilities tend to support LIBs end-of-life management initiatives mainly by joining highly volatile partnerships in external projects given that supply chain members are still not committed to environmental challenges resulting from LIBs end-of-life. Being only marginally based on internal and structured R&D activities, these initiatives and projects reflect corporate frugal and short-term perspectives on LIBs end-of-life management that often lead to the release of just incremental innovations of soft procedures. Therefore, the collaborations (partnerships) implemented are not able to address the complexities associated with the LIBs end-of-life management (Hickle, 2017).

Nevertheless, it is important to note that most of the above-mentioned projects and collaborations originate from the downstream supply chain, which leads to two important considerations. First, the innovation process is led by a variety of SMEs that look at energy utilities as a key player for demonstrating the market potential of their solutions. Energy utilities, thus, influence innovation pathways throughout the supply chain because they aggregate large volumes of demand. Moreover, since energy utilities are not involved in similar initiatives with LIBs producers interested in take-back options, which means that LIBs producers are far from closing the loop of LIBs materials, they de-facto are alone in fostering the coordination of the LIBs sustainable supply chain management. Therefore, they need new relationships with third parties not generally associated with the supply chain (Miemczyk *et al.*, 2016). Second, the lack of structuration of the partnerships between energy utilities and, upstream and downstream LIBs supply chain actors leaves some open questions concerning the actual possibility for this industry to achieve full compliance with the LIBs extended producer responsibility principle for an effective and economically efficient product recovery system. In fact, there are still many uncertainties on how the variety of initiatives from the upstream and downstream side of the supply chain might lead to the structuration of a sustainable LIBs supply chain.

Therefore, LIBs should be considered a promising technology with unclear futures due to the lack of evidence that the large amount of investments in user-oriented performance improvement will be able to adequately address also all those environmental issues that, throughout the life-cycle, are instead becoming more and more urgent. Given the recorded inertia in structuring a LIBs sustainable supply chain along the last ten years, it is not unlikely that the final solution will consist in the introduction of alternative technologies and, thus, in the substitution of LIBs with intrinsically “greener” solutions.

Therefore, the research provides two main theoretical implications. First, the lacking mention of LIBs end-of-management initiatives in corporate sustainability reports reveals a stasis in the nature of the related collaborations by confirming similarities of strategic postures among supply chain actors in terms of the identification and adoption of short-term and marketable solutions. This limits the availability of options for tackling future challenges within the supply chain.

Second, the long-term structuration of the supply chain is negatively affected by the existing collaborations, which hinder a strategic and systemic vision for the sustainable supply chain and accordingly increase the supply chain vulnerability to alternative technologies.

Moreover, the findings of this study also provide some managerial implications. First, companies can employ the currents trends in sustainability reporting to design and implement strategies in sustainable supply chain management for building their legitimacy as sustainability leaders.

Second, managers involved in capital-intensive investments on fast evolving technologies should be encouraged to reflect on the opportunities for end-of-life management practices not simply because of cosmetic reasons regarding the corporate reputation but also because of the need to reduce risks associated with the volatility of the extended value chain by evaluating the possible measures and key partners to modify the existing supply chain or integrate/create new ones.

Third, companies located in focal positions of the supply chain, such as energy utilities, in lack of signals of a structuration of downstream networks for end-of-life management, should balance demonstration projects both on the downstream and upstream sides of the supply chain, so as to scout possible emerging and green-by-nature technologies by gathering all information to assess all possible environmental impacts and make informed decisions.

However, some limitations must be acknowledged. First, we derive our results from the cross-validation of secondary data sources, namely company websites, online press releases and corporate sustainability reports. Since we analyzed the subjectivity of corporate thinking concerning sustainability strategy and practices, we do not need the same level of objectivity in the raw data as investigations on sustainability indicators and, thus, we assume the reliability and consistency of this data for our study. Despite that, we do not have access to information regarding undisclosed strategic activities of energy utilities, which can provide evidence of future corporate initiatives and activities. Second, the use of publicly accessible web sites and corporate sustainability reports consists of concise bunches of information describing practices that have achieved a certain maturity within the organization. Consequently, the information provided in sustainability reports might be sufficient to understand the positioning of similar companies, but not enough detailed to fully appraise the actual commitment and efforts towards LIBs end-of-life management when compared with other internal priorities. Third, since our sample is based on energy utilities, which are very often considered sustainability leaders, some caution should be used when applying our insights to companies that do not have the same level of maturity in sustainability and its reporting.

Future research should expand our analysis by further exploring the internal tensions and motivations of adoption or non-adoption of LIBs end-of-life management practices based on interviews or focus groups with the involved managers. Moreover, future studies can develop a cross-analysis extending the search for end-of-life management initiatives in other sectors influenced by the diffusion of LIBs.

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