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Review

Towards sustainable business models for electric vehicle battery second use: A critical review

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ABSTRACT

A global mass market adoption of electric vehicles (EVs) is still hindered by the high costs of lithium-ion batteries (LIBs). Repurposing degraded EV batteries in second use applications holds the potential to reduce first-cost impediments of EVs. New business models are emerging rapidly within the EV and battery second use (B2U) industries but they focus on economic aspects without integrating social and environmental dimensions. Simultaneously, the emerging research topic around sustainable business models (SBMs) seem to be able to bridge the environmental management concerns in conjunction with economic and social changes. This paper addresses this paucity in the literature by offering an interdisciplinary approach by drawing upon key perspectives from the emerging sustainable technology of EVs and its underlying B2U market in relation to SBMs. Findings reveal major contributions to theorists and practitioners. B2U holds the potential to facilitate current unsustainable practices in the EV industry. This in turn, will lead towards a faster EV market uptake and improvements of overall sustainability performance through SBM perspectives. Accordingly, a B2U business model framework is conceptualised that embodies the cross-sector multi-stakeholder impact and the shared value creation mechanism for the EV industry and emerging B2U market. We finally conclude that as such B2U holds the potential to prove itself to be a viable and efficient case for sustainability. This can be implemented by taking a multi-stakeholder network centric business model design compared to traditionally firm-centric models, which ultimately refreshes the traditional business models on sustainability.

1. Introduction

In the last few decades, global concerns over climate change as a result of a rising global population and related increasing resource use and environmental impacts have strengthened the need to shift towards holistic approaches that challenge the issues of a more sustainable future. In fact, the transport sector is one of the key contributors to global greenhouse gas (GHG) emissions to the atmosphere due to ever-increasing uses of finite fossil fuels and ongoing dependency on internal combustion engine vehicles (ICEVs) for more than a century, which emphasize that current economic, social, and environmental structures within the automotive industry are unsustainable (Ahmadian et al., 2018; Casals et al., 2017). These concerns alongside an increased focus on sustainable transportation have stimulated a trend within the automotive sector towards electric vehicles (EVs), which are a promising solution to restrict such emissions. However, a global mass market adoption of EVs is still hindered by presently high costs of lithium-ion battery (LIB) packs, which translate into highly priced vehicles (Bonges and Lusk, 2016).

Among other possible solutions to make EVs more affordable, the concept of battery second use (B2U) has been identified as one promising value creation mechanism that could feed back some revenue to EV manufacturers that may lead to lower vehicle selling prices, and thus making EVs more competitive (Jiao and Evans, 2016a). Once degraded, the second use of EV batteries in less demanding stationary energy storage systems (ESS) presents a cost effective option that can contribute to building smart grid technologies (Podias et al., 2018; Neubauer and Pesaran, 2011). In this second life, the batteries can be procured at low cost, indicating new businesses opportunities.

Through remanufacturing and reuse, the concept of B2U slows down the resource cycle by prolonging the battery's total service life and partially closes the resource loop as the recycling phase is delayed

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substantially, leading towards improved sustainable resource management. Therefore, it is line with the principles and different interpretations of the circular economy, which all have in common that resource life extending strategies are the most essential element (Antikainen et al., 2016). Given the concept of B2U, it must be highlighted that product life extending strategies are crucial to decrease negative impacts on the environment and to contribute towards the circular economy. However, it is still unclear how a firm might translate such strategies into innovative business models (Bocken et al., 2016a). In this regard, Boons and Lüdeke-Freund (2013) argue that sustainable business models (SBMs) can significantly contribute to solving economic, ecological and social problems simultaneously. Consequently, this review follows the argument that the emerging B2U industry can deliver not only economic value but also social and environmental values as part of SBM approaches.

However, it seems that neither theoretical nor empirical research has yet answered the question what these business models entail and how they will develop in the future. According to Yang et al. (2017a) current research efforts in the field of SBMs is not yet mature, stating that there is "… a lack of agreed concepts of sustainable business models and the ways to achieve this being poorly addressed in literature" (p1796). Rana et al. (2017) also relates to this lack of research and existing works on SBMs and modelling approaches, stating that current frameworks tend to be limited in their research scope and a more holistic view of the three metrics of sustainability, the environment, society, and the economy, is needed. SBM research is slowly gaining a foothold but the concept itself still lacks clarification in practice, particularly the development of SBM theory is still in its infancy (Dentchev et al., 2018). In a recent analysis on developments in SBM scholarship and practice, Lüdeke-Freund and Dembek (2017) have assessed whether SBM research is an emergent field or a subfield of already established theories and concepts, concluding and confirming that in fact SBM research is an emerging field. On the other hand, only very few studies have assessed B2U from a business model perspective and consequently follow-up studies are in demand that evaluate the increased value of reusing EV batteries (Jiao and Evans, 2017).

With prospective increased global EV market share, a growing number of retired EV batteries will become available at low cost that could provide valuable services in stationary ESS. For this reason, end-of-life (EOL) EV batteries may represent a disruptive technology that will change the current nature of the automotive and energy industries as the electricity markets presently lack cost-effective ESS as well as that B2U may represent much cheaper electricity storage from renewable than is available today. Consequently, there is the opportunity of an attractive market not only for original equipment manufacturers (OEMs) but also for new market participants such as electricity producers, grid operators, recycling companies, service providers and final costumers, which all will be part of innovative evolving value chains. Thus, potential B2U strategies are dependent on many factors, particularly on the interests of the different stakeholders involved, which underlines that articulating effective business models will be difficult. Recently, the concept of B2U is a much-debated issue within the automotive industry (Jiao and Evans, 2018) and nearly all of the major car companies have participated in pilot and demonstration projects as part of joint ventures with other stakeholders to gain a better understanding about the feasibility and the capabilities of B2U and development of viable innovative business models (Table 1). It is evident that there is a growing investment, experimentation, and interest on the topic of B2U, indicating the creation of a secondary market for retired EV batteries including newly forming stakeholder relationships and hence new market opportunities.

However, most of these projects have served as demonstration and pilot projects due to low availability of degraded EV batteries (*i.e.* slow EV market uptake) as well as uncertainties on quantifying the true economic value of these batteries. Thus, developments in the nascent B2U industry are speculative at this point as companies entering into this evolving market are still evaluating if B2U is a profitable business or not. Hence, potential B2U market forms, economic properties or identified stakeholders involved through the establishment of mature business models is far from becoming a reality (Bräuer, 2016). Today, there are new business models developing within the EV and emerging B2U industry but they mainly focus on economic aspects without integrating social and environmental dimensions as part of SBM solutions (Jiao and Evans, 2016a).

Therefore, the necessity for this review arose from the limited ability of current business model approaches to quantify the full scope of B2U from SBM perspectives. For this reason, the objective of this review is to explore the EV EOL strategy of B2U from a SBM perspective. In doing so, this review addresses the following research questions:

RQ1. Unearth and record the intercorrelation between the EV sector and emerging B2U market, considering SBM perspectives

RQ2. Explore how the B2U market and prospective (sustainable) business models develop from a stakeholder perspective

The paper is structured as follows. First, the representation of the literature synthesis on the concept of the battery second use life cycle and business models towards sustainability is presented in chapter 2. This is followed by a description of the employed methods in chapter 3 and results in chapter 4. The paper concludes with a discussion on the intercorrelation between SBMs and B2U in chapter 5 and conclusions and contributions (chapter 6).

2. Literature synthesis

2.1. Electric vehicle battery second use lifecycle

The lifecycle of EV batteries conceptually begins with the extraction of raw materials (including mining and processing) to battery manufacturing, the primary use in the EV (1st life), followed by end-of-life disposal (Neubauer et al., 2015; Neubauer and Pesaran, 2011; Reid and Julve, 2016; Richter et al., 2016; Ahmadi et al., 2014b). Considering the integration of the concept of B2U, an additional loop has been added including battery refurbishment and second life application in grid storage, which substantially extends the battery lifecycle in comparison to a more linear approach and is thus in line with the cornerstones of the circular economy (Fig. 1).

A lithium-ion battery (LIB) pack's **first life** includes the manufacturing of the battery and its effective and low carbon operation in an EV whereby the battery provides electrical operating power for the motor and auxiliary units whenever needed (Rehme et al., 2016). An EV battery's first life in an automotive application is characterised by different driving patterns, operating temperatures and charging rates, which makes each battery age individually and it is therefore difficult to predict a battery's aging behaviour (Knowles and Morris, 2014).

Furthermore, in the EV's first life, the vehicle can act as a distributed energy storage device and can offer many service such as through EV charging (vehicle-to-grid), the vehicle's rechargeable battery provides power to the grid that can help to balance loads by *e.g.* charging at night time when demand is low (so-called 'valley filling') or send power back to the grid when demand is high (so-called 'peak shaving') (Yong et al., 2015). These grid operation and management potentials have received increased attention from the electricity markets, particularly with regards to effectively balancing the grid. This is a direct result of growing policy pressures on decarbonising the electricity generation through integrating increased volumes of renewable energies. As a result, EV companies such as Nissan and Tesla have entered the stationary storage market for residential and commercial uses by installing their own stationary storage solutions that facilitate in learning about this technology while generating some revenue (Reid and Julve, 2016).

However, the integration and storage of intermittent renewables in large-scale ESS still lacks cost-effective solutions due to expensive LIB

Table 1
Available B2U projects (pilot & commercial).

OEM	B2U partner/service provider	EV model	Capacity	B2U application	Country	Reference
Daimler	GETEC, The Mobility House, Remondis	Smart	13 MWh	Renewable energy	Germany	Daimler, 2016
GM	ABB	Volt	50 kWh/25 kW	Power supply	USA	ABB, 2012
GM	ABB	Volt	n/a	Renewable energy	USA	(General Motors , 2015)
Renault	Eco2Charge	Kangoo ZE	66 kWh	Renewable energy	France	(Eco2Charge, 2014)
Nissan	Eaton	Leaf	4.2 kWh	Residential energy storage	UK	Nissan, 2017a
Nissan	Eaton & The Mobility House	Leaf	4 MWh/4 MW	Peak shaving, Backup power	Netherlands	Nissan, 2016
Nissan	Sumitomo	Leaf	400 kWh/600 kW	Renewable energy	Japan	(St.John, 2015)
Mitsubishi & PSA	EDF & Forsee Power	Peugeot Ion, C-zero & iMiev	n/a	Renewable energy	France	Green Car Congress, 2015
BMW	UC San Diego	Mini-E	160 kWh/100 kW	Renewable energy	USA	California Energy Commission, 2012
BMW	Vattenfall & Bosch	ActiveE & i3	2.8 MWh/2 MW	Renewable energy	Germany	Lambert, 2016
BMW	Vattenfall	i3	12 kWh/50 kW	Fast charging	Germany	BMW, 2014
Renault	Connected Energy	Zoe	50 kWh/50 kW	Fast charging	UK	Renault, 2017a

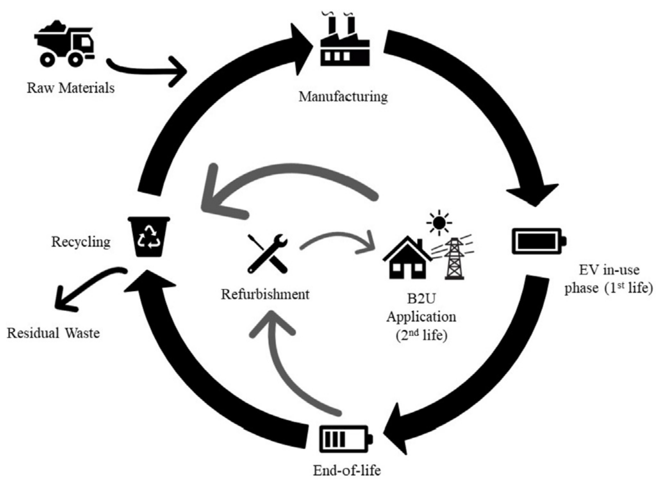

Fig. 1. Life cycle of electric vehicle batteries considering battery second use.

packs (Heymans et al., 2014). This is confirmed by Casals et al. (2019), stating that LIB pack prices would need to be below 220 dollar per kilowatt-hour ($/kWh) to result in substantial revenues as part of stationary ESS. B2U solutions in the stationary storage market can therefore perform the same services at substantially lower cost and may unlock the potential to feedback revenue to EV companies that will in turn lead to lower vehicle prices (Jiao and Evans, 2016b). However, it must also be underlined that with ongoing battery price reductions, the concept of B2U may face strong competition from new, cheaper, and specifically for ESS purposes designed batteries.

An EV battery reaches its **EOL** when it can no longer meet the requirements of the vehicle operation (reduced maximum range and decreased acceleration) and typically customers bring their EVs to the dealership when the vehicle is performing below the customer's expectation (Cready et al., 2003). An EV battery is considered not useful for traction purposes and has degraded after losing around 20%–30% of its capacity or after around 4,000 charge cycles or 120.000 km of driving (Ahmadi et al., 2015; Neubauer et al., 2015; Sathre et al., 2015). As these batteries still retain around 70%–80% capacity, researchers have found that instead of recycling these EOL batteries immediately after their first use in an EV, repurposing degraded EV batteries in a second life in less demanding stationary ESS is still possible and feasible form a techno-economic and environmental perspective (Cready et al., 2003; Wolfs, 2010; Gaines and Sullivan, 2010; Neubauer and Pesaran, 2011; Ramoni and Zhang, 2013; Manzetti and Mariasiu, 2015).

The **refurbishment** process usually entails costly reengineering of an EV battery for a non-vehicle stationary storage application through battery disassembly, testing degradation and failure rates, repairing any damages, removal and replacement of substandard cells, reassembly of the module and pack, packaging for B2U application and adding electrical hardware, control and safety system (Derousseau et al., 2017; Standridge and Hasan, 2015; Foster et al., 2014; Ahmadi et al., 2014a; Cready et al., 2003). Today, EV batteries consist of many components such as lithium-ion cells, battery management systems, sensors and cooling systems, which in principle can all be re-used in B2U concepts (Fischhaber et al., 2016). However each degraded EV battery has its own individual state of health depending on the previous exposure and treatment during their first-life and therefore costly manual disassembly processes are presently the norm as each battery must be cleaned, inspected and replaced to reach like new condition (Ramoni and Zhang, 2013). Therefore, a standard testing procedure is urgently needed so that degraded batteries can be safely used in B2U applications. Further, it must be underlined that today there exists no widely-accepted standard for B2U at the initial battery design stage ('design for B2U') or once the battery has reached its first EOL. Therefore researchers are calling for increased battery quality standards and certification protocols to ensure safe and effective functioning in B2U applications as well as underline the importance of collaborations between EV companies and battery makers *i.e.* original equipment manufacturers (OEMs), in order to develop standardised battery components and models to ensure cross-manufacturer compatibility (Hu et al., 2017).

After the batteries have been repurposed, they are ready for use in a **B2U application**. Today, across the literature the most prominent B2U strategy has been identified to be the battery repurposing and further use in non-automobile stationary ESS (Derousseau et al., 2017; Beverungen et al., 2016; Bräuer et al., 2016; Jiao and Evans, 2016b; Standridge and Corneal, 2014; Foster et al., 2014; Ahmadi et al., 2014a; Ambrose et al., 2014; Neubauer and Pesaran, 2011; Narula et al., 2011; Williams and Lipman, 2010). Previous research in the field concluded that the most environmentally and economically beneficial B2U application markets for EV traction batteries lay within industrial and residential uses including current and emerging grid-related applications (Gaines and Sullivan, 2010; Neubauer and Pesaran, 2011; Standridge and Corneal, 2014). According to Burke (2009) the most efficient B2U applications are within the residential sector (*e.g.* buffer for renewable energy) in contrast to large-scale storage system as the refitting process requires more efforts and costs. Williams and Lipman (2011) and Narula et al. (2011) on the other hand, estimate that the most economic use is the application in large-scale stationary ESS. Ambrose et al. (2014) demonstrated that applying second life EV batteries to microgrid systems in developing countries in contrast to using lead-acid batteries has shown several economic and environmental benefits, which has been confirmed in studies by Neubauer et al. (2012) and Neubauer and Pesaran (2011).

According to Rehme et al. (2016), with regards to the ESS's degree of mobility, B2U application cases can be classified in stationary (*e.g.* home storage from PV panels), semi-stationary (*e.g.* power for construction sites), or mobile (*e.g.* reuse in scooters or golf cars). Törkler (2014) on the other hand, identified three possible B2U applications depending on the needed energy that are energy related and industrial applications, commercial applications, and residence related applications. Consequently, the battery management system needs to be adjusted to the specific B2U stationary storage application to increase overall lifetime and economic benefits (Reid and Julve, 2016). In that context, it must be underlined that there is pressing need for regulation, especially within the European Union (EU) legal context, to address the emerging technologies and relationships between EVs (including B2U) and energy storage technologies as they arrive at the markets in a more proactive manner. According to Reinhardt et al. (2016) EU automotive and energy binding legislations have to work for a more harmonised policy framework, ultimately leading to provide a level playing field for an electric mobility (e-mobility) transition within the European economy. It appears that the European Commission has comprehended the need to overcome such regulatory barriers to innovation as of March 2018, an innovation deal with eight partners from national authorities and innovators has been signed, which aims to clarify the regulatory landscape regarding of EV battery EOL solutions (including B2U and recycling) and stationary ESS applications (European Commission, 2018).

The concept of B2U has the potential to delay the battery **recycling** process by 10–20 years, which is usually implying additional costs for OEMs and entails potential waste and environmental pollution. The industry presently lacks proper environmental sound and economic feasible recycling framework for automotive LIBs on a large scale as well as that it has been claimed that recycling is often motivated by economic revenues (Yun et al., 2018; Sonoc et al., 2015; Gaines et al., 2011). This raises a major sustainability concern on the possible unregulated disposal of EOL EV batteries that can have significant negative effects on the environment and human health (*e.g.* risk of fires during battery transportation/storage) as it was found to be the case by the unchecked disposal of consumer electronic waste (e-waste) in the past (Richa et al., 2014; Widmer et al., 2005). From an economic perspective, battery recycling facilities require high fixed costs and thus need high utilisation (large volumes of batteries) to become economically feasible (Rohr et al., 2017). In recent years, much research has focused on recycling waste LIBs while simultaneously battery recycling industry infrastructure remains insufficient with only few companies such as Umicore, Sony and Accurec having exploited technologies to recycle spent EV batteries on a large commercial scale (Heelan et al., 2016; Sonoc et al., 2015).

Overall, the concept of B2U delays recycling efforts and may lead to higher residual value of the battery that could improve overall economic efficiency of EVs. Therefore, previously considered as a waste and recycling issue, reusing spent LIBs as part of B2U solutions may now lead into profitable innovative business models towards sustainability that is yet to be fully unearthed for researchers, industry and policy makers.

2.2. Business models

The term 'business model' has not been widely discussed across the literature until the 1990s with the introduction of the dotcom age but then reached a relatively good conceptual understanding but due to its complexity no single definition of the term exists. The existing key literature presents various perspectives in a static approach on what business models entail whereby the focus is on how a firm creates and captures value within a value network (Bocken et al., 2014; Zott et al., 2011; Teece, 2010; Zott and Amit, 2008; Osterwalder et al., 2005; Chesbrough and Rosenbloom, 2002; Osterwalder and Pigneur, 2002). This view reflects common agreements among other strategy-oriented business model scholars that creating and delivering customer value lies at the centre of any business model and thus its central element is the customer value proposition (Chesbrough, 2010; Johnson, 2010; Teece, 2010; Zott and Amit, 2010). Further, the literature conceives a business model as firm-specific whereby different components of the business model interact with each other to address change and focus on innovation (Demil and Lecocq, 2010). Thus, researchers have investigated how a business's activities as part of a business model are interlinked to provide value that may lead into a competitive advantage.

In that regard, one widely accepted tool is the business model canvas, which determines nine elements of any business model that make up the whole system that are value proposition, customer segments, customer relationships, channels, key resources, key activities, partners, costs and revenues (Osterwalder et al., 2010, 2005). Based on a wide range of literature, Richardson (2008) proposes a widely accepted framework for business models, which contain the value proposition, value creation and delivery and value capture. Boons and Lüdeke-Freund (2013) combine approaches by various authors and distinguish the following elements of a generic business model concept, which are value proposition (the value embedded in the products/services offered by the firm); supply chain (the relationships with suppliers); customer interface (the relationships with customers); and financial model (cost and benefits, and their distribution across the stakeholders). Based on these concepts, across the literature three core interrelated characteristics of business models have emerged and can be summarized as: the value proposition, value creation and delivery and value capture (Fig. 2).

To keep competitive advantages, firms need to continuously innovate their business models. In searching such innovative ways, business model innovation (BMI) has been acknowledged as a source of competitive advantage as it has the strategic potential to identify new sources of value creation through innovating the different elements (and their interactions) of the business model (Amit and Zott, 2012;

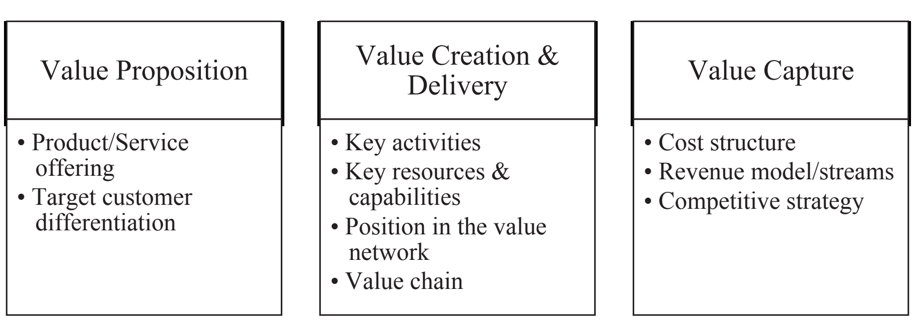

Fig. 2. Business model framework (adapted from Bocken et al., 2014; Richardson, 2008; Osterwalder et al., 2005)

Bocken et al., 2014). BMI is defined as "… the search for new logics of the firm and new ways to create and capture value for its stakeholders" (Casadesus-Masanell and Zhu, 2013, p464). As the topic of sustainable development is increasingly identified as a new source of competitive advantage, the concept of BMI is seen as one of the key tools to make strategic use of sustainability in organisations (Zhang et al., 2018; Abdelkafi and Täuscher, 2016; Boons and Lüdeke-Freund, 2013). Since the release of the Brundtland Report in 1987, which defines sustainable development as "… development that meets the needs of the present without compromising the ability of future generations to meet their own needs", the concept has been playing an increasingly critical aspect in agendas of policy makers and strategies of businesses (WCED, 1987, p43). Particularly relevant to the term sustainable development is the 'triple bottom line' (TBL), which aims to a balanced integration of the environment (planet), society (people) and economy (profit) (Elkington, 1997).

The recent global financial and economic crisis alongside a rising global population that is consuming ever-increasing volumes of resources, has further led to important questions on the impact of existing corporate business models on the sustainability of the global economy and society (Schaltegger et al., 2016). Scholars have thus argued that if companies are to fully contribute to sustainable development, they need to rethink their business models and fundamentally shift their business activities and innovation practices to achieve deeper incorporation of environmental and social issues and needs as part of a future sustainable economy (Bocken et al., 2014; Boons and Lüdeke-Freund, 2013; Lüdeke-Freund, 2010; Stubbs and Cocklin, 2008). This is why the concept of BMI is increasingly recognised as a mechanism that enables to identify greater social and environmental sustainability in the industrial system (Lüdeke- Freund, 2010).

Scholars and experts are increasingly exploring whether adapted or completely innovative business models can boost economic revenues by either drastically diminishing negative influences or developing positive impacts for the environment and society (Boons and Lüdeke-Freund, 2013; Schaltegger et al., 2012; Stubbs and Cocklin, 2008). Major beliefs among scholars is that the normative concepts of sustainable development with the help of BMI should guide the development and implementation of more sustainable business models, which has been identified as the 'well-rooted foundational idea' in order to contribute solving economic, environmental and social problems (Lüdeke-Freund and Dembek, 2017). This fundamental change will require a holistic approach that can tackle the challenges of a sustainable future through bringing responses to environmental changes in conjunction with economic and social changes, ultimately leading to more sustainable business models (SBMs) (Bocken et al., 2014).

2.3. Sustainable business models

The concept of sustainable business models (SBMs), or also referred to as business models towards sustainability, has emerged within the last decade with works by Stubbs and Cocklin (2008) evaluating organisational and cultural preconditions of business models that contribute positively to environmental and social development (Lüdeke-Freund and Dembek, 2017). In the following years, the interest of academia in SBMs research has increased with the publication of special issues such as in *Organization and Environment* (Volume 29, March 2016), *Journal of Cleaner Production* (Volume 45, April 2013) and *Sustainability* (Volume 8, 2016) along review articles (Geissdoerfer et al., 2018b; Evans et al., 2017b; Schaltegger et al., 2016; Bocken et al., 2014; Boons and Lüdeke-Freund, 2013), which all provide excellent overviews and different perspectives on the topic.

Early works on the topic by Stubbs and Cocklin (2008) state that SBMs use both a systems and firm-level perspective, based on the triple bottom line (TBL) approach, to define the businesses' purpose and measure performance, include a wider range of stakeholders, and consider the environment and society as stakeholder. The main objective of SBMs is to go beyond creating merely economic value but to achieve a harmony of all stakeholders' interest to create positive sustainable value creation by considering the environment and society as key stakeholders (Bocken et al., 2013).

Lüdeke-Freund (2010) defines SBMs as "… a business model that creates competitive advantage through superior customer value and contribute to a sustainable development of the company and society" (p21). This study further advances towards conceptual models for SBMs underlining that sustainability practices arise through the connection of ecological development and business development (*e.g.* efficiency and consistency). Recently, Schaltegger et al. (2016) provided a more accurate definition in combining the findings from different scholars, stating that a SBM "… helps describing, analysing, managing, and communicating (i) a company's sustainable value proposition to its customers, and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries" (p3).

Therefore, the concept of SBMs are defined by integrating the cornerstones of sustainable development into the core of the conventional business model and modifying it by creating economic, social and environmental value through more pro-active collaboration with all stakeholders (Geissdoerfer et al. 2016, 2017). To successfully include sustainability into business models, companies must not only consider economic value, which is usually comprehended in monetary measures, but also the benefits of society and the environment, commonly referred to as sustainable value (Evans et al., 2017a). Further, according to Geissdoerfer et al. (2018a), sustainable value along pro-active multi-stakeholder engagement and long-term perspective are the three key parameters that will …"utilise the sustainable business model's analytical, strategic and communicational potential to integrate sustainability considerations on the organisational level" (p713).

Additionally, there are some practical tools for sustainable value creation available among the literature. Despite the complexity around SBMs, practical tool development efforts amongst researchers are increasingly in demand but still very rare (Geissdoerfer et al., 2016; Evans et al., 2014). First developments in the SBM tools area have been made by some authors such as the introduction of the value mapping tool (Bocken et al., 2013), sustainable value analysis tool (Yang et al. 2014, 2017b, 2013), the flourishing canvas (Upward and Jones, 2016) and the triple layered business model canvas (Joyce and Paquin, 2016). Even though these tools and approaches are rare among current literature, they have a tendency to focus only on distinct phases of the innovation process (Geissdoerfer et al., 2016). This is further supported by Lüdeke-Freund and Dembek (2017) who found that tools and other forms of practical guidance are in demand to convert SBM concepts into business model designs that as a consequence will lead to organisational development and operational activities in practice.

Moreover, the literature discusses a variety of generic strategies, subcategories and archetypes for SBMs such as circular business models, product-service systems, social enterprises and base of the pyramid (Tukker, 2015; Bocken et al., 2014). For instance, according to Geissdoerfer et al. (2018b) circular business models do not only create sustainable value, support pro-active multi-stakeholder management and long-term perspective but also close, slow and narrow resource loops (Bocken et al., 2016a). But as a result of the different features as well as previously discussed characteristics that classify a SBM, there may be cases where merely a sub-category is fulfilled without meeting the characteristics of a 'true' SBM (Fig. 3) (Geissdoerfer et al., 2018b).

These sub-categories and strategies were reviewed by Bocken et al. (2014) and synthesised as generic SBM strategies, the so-called SBM archetypes, which aim to accelerate the development of SBMs in theory and practice and advance towards a unifying research agenda. The archetypes provide major orientations of diffusion of new and clean technologies, social innovations and organisational solutions that could contribute to building up the business model for sustainability (Bocken

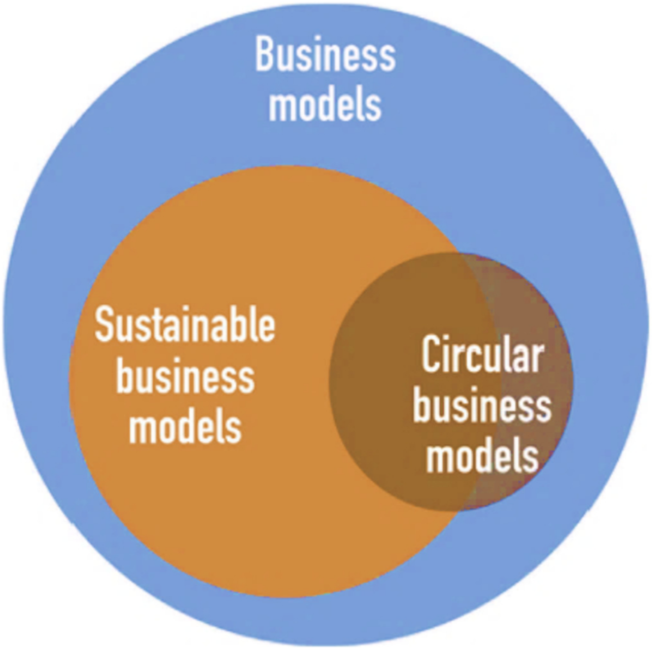

Fig. 3. Overlap of the sustainable business model concept and its subcategories such as circular business models (Geissdoerfer et al., 2018b).

et al., 2014).

Recently, the archetypes have been further developed by Bocken et al. (2016b) and Lüdeke-Freund et al. (2016) to include nine archetypes distributed to environmental, social and economic categories as the major innovation types derived from the concepts of sustainable development and the TBL approach (Fig. 4) (Ritala et al., 2018; Elkington, 1997). These archetypes are considered as extremely important amongst fellow researchers since they represent typical examples of solutions that contribute to establish SBMs in theory and practice. However, despite their momentous potential with emerging innovative solutions as it might be the case with EV B2U, and a noticeable call for action to tackle pressing issues such as pollution and resource scarcity, the generic SBM strategies have not been accepted by industry yet (Despeisse et al., 2017).

3. Methods

An important first realisation stands out for theorists through a preliminary theoretical investigation. It seems that an investigation of the interdisciplinary relationship between the two emerging research topics of B2U and SBM perspectives has not been previously attempted in such a broad context and overarching content. Given the exploratory research context where little or no information is available along the identified research questions, this review follows an analytical inductive reasoning (Goddard and Melville, 2004). Therefore, a structured review or meta-analysis on the topic was not possible because of non-comparable research results across the literature. Rather, the authors decided to apply a review process in the form of qualitative content analysis through an extensive annual search across the literature, interpretation of the content of text data through systematic classification processes of cording and identifying themes and summarizing relevant findings. Therefore, we emphasised our primary research focus on the previously discussed research questions, the identification and analysis of sustainable business model (SBM) perspectives for the emerging concept of electric vehicle (EV) battery second use (B2U).

Data were collected from reputable sources, mainly peer reviewed literature, but also to some extent from grey literature (*e.g.* company releases) and news and press releases due to the nascent stages of both evolving major research streams. Further, a variety of inclusion and exclusion criteria for the literature and document search was identified and applied (Table 2).

Therefore, it was crucial to conduct an interdisciplinary review of both business and science databases to meet the review scope. We searched academic databases (*e.g.* Science Direct, Scopus, JSTOR, ProQuest, Web of Science, Social Science Citation Index, SpringerLink), Web search engines (*e.g.* Google and Google Scholar), and available catalogues on grey literature (*e.g.* British Library Catalogue) and to some extent news/press releases. The inserted keyword search included a combination of "electric vehicle battery second use", "electric vehicle battery reuse", "business model innovation electric vehicles", "sustainable business models", "business models for sustainability", and "sustainable business model innovation". These terms were reassessed through an ongoing iterative process until data saturation was reached as well as the application of the snowball sampling method in order to recognise relevant literature from the reviewed research. The coding, synthesis and analysis of data was undertaken manually and in accordance with the identified research questions along the applied inclusion and exclusion criteria. Results are not intended to provide

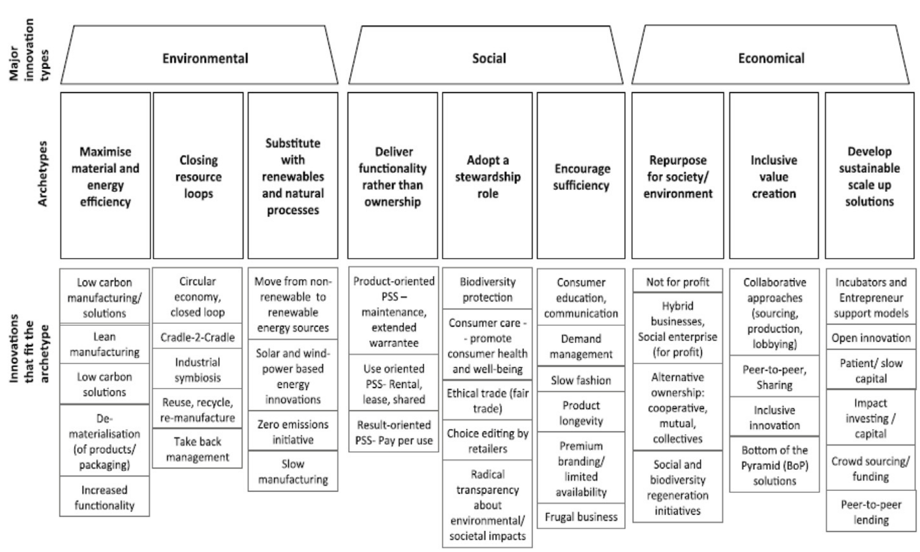

Fig. 4. Sustainable business model archetypes (Bocken et al., 2016b, 2014; Lüdeke-Freund et al., 2016).

Table 2
Inclusion and exclusion criteria for literature search.

Included	Excluded
Qualitative studies with an emphasis on: - innovative sustainable business model theory, tools, frameworks and case studies - electric vehicle battery second use innovative business model perspectives	Quantitative studies with an emphasis on: - electric vehicle battery second use environmental and techno-economic assessments with no implications for (sustainable) business model evolution in the electric vehicle sector and underlying B2U market Research studies on sustainable business model sub-categories and themes (*e.g.* circular economy, closed loop system, remanufacturing)
Type of study: peer reviewed journal articles, conference papers and book chapters Non-peer reviewed: grey literature coupled with news/press releases on recent innovative B2U industry activities	Type of study: non-peer reviewed journal articles, theses/dissertations

Table 3
Battery second use techno-economic studies and findings.

Findings	Reference
Increase of EV LIB lifetime and subsidy to the business case as high initial cost of batteries is decreased	(Neubauer et al., 2012; Narula et al., 2011; Neubauer and Pesaran, 2011)
B2U in stationary ESS (*e.g.* intermittent renewable storage) offers revenue at low cost for the energy markets and enhances utility operation (*e.g.* relieve the public grid)	(Beer et al., 2012; Lih et al., 2012; Neubauer et al., 2012; Gaines and Sullivan, 2010; Williams and Lipman, 2010; Cready et al., 2003)
Enormous economic potential as B2U in stationary ESS is price competitive to current costs for ESS with 'newly' fabricated batteries	(Rohr et al., 2017; Gaines and Cuenca, 2000)
Highlight the significance of a favourable regulatory framework	(Heymans et al., 2014; Wolfs, 2010)

concrete answers to the new research field but rather identify first patterns and lessons in both emerging research fields.

This screening process confirmed the necessity of this interdisciplinary review article as through evaluating existing research on the topic it became evident that most research in the context of B2U has been delivered mainly in the form of quantitative studies on the techno-economic (Table 3) and environmental feasibilities (Table 4).

Further, these studies concluded that no major technical barriers were identified but increased research efforts on the feasibility of effective (sustainable) business models should be further studied in practice (Elkind, 2014; Foster et al., 2014; Heymans et al., 2014; Beer et al., 2012; Neubauer et al., 2012; Lih et al., 2012; Narula et al., 2011; Wolfs, 2010; Williams and Lipman, 2010; Gaines and Sullivan, 2010; Cready et al., 2003; Gaines and Cuenca, 2000). Moreover, a comprehensive study by Jiao and Evans (2017) found that these studies are quantitative, require detailed breakdowns of the technical, economic or environmental parameters and are limited in their boundary conditions due to the uncertainties of the parameters (no or limited data available) in the emerging stage of the B2U industry and therefore call for a substantial increase on B2U research efforts from a (sustainable) business model perspective. Bocken et al. (2015) supports this view, concluding that tools such as LCA have the tendency "… to be narrowly used on a limited range of parameters such as energy and carbon, rather than offering a holistic perspective for analysis embracing all stakeholder considerations, and particularly social dimensions" (p69). This is further underlined by Patala et al. (2016), relating to previous research efforts excessively concentrating on environmental impacts, stating that this may delay "… a promotion of ecologically beneficial offerings, and emphasizing the economic benefits of the offering might facilitate their more widespread business acceptance" (p147).

Therefore, we extend our understanding and underline the interconnectivity of business models to the managerial fields of social, environmental, and economic relevance through an empirical investigation of B2U and the interaction with SBM perspectives and emerged concepts. Another major contribution to professionals and practitioners will be the identification of the process of how prospective SBM perspectives in the context of B2U can ease or even solve current unsustainable practices in the overarching EV industry. A recent study by Lüdeke-Freund and Dembek (2017) emphasizes that inter- and trans-disciplinary research efforts are required to better comprehend changes of businesses towards sustainability as part of SBM approaches and the authors conclude that as a result "… a series of critical reviews could be a starting point for such an endeavour" (p1168). This is in conjunction with recent research efforts in the global business research community, which underline that the identity and legitimacy of international business (IB) as a field is at stake due to the increasing interconnectedness of the world along ongoing evolution of industries and technologies (*e.g.* industrial revolution 4.0). A recent study by Poulis and Poulis (2017) deliver an ontological perspective on the disciplinary tautology of IB and the authors demonstrate that a lack of ontological clarity undermines IB's sustainability. The authors argue that to redraw legitimate knowledge boundaries for IB an ontological shift is required, which may be achieved through turning to other fields for illumination by skilfully applying interdisciplinary research efforts that in turn can

Table 4
Battery second use environmental studies and findings.

Findings	Reference
EV in-use phase represents most critical phase with regards to emitted GHG (unsustainable charging sources 'green washing') Studies are limited to the EV battery production and use phase	(Ellingsen et al., 2014; Hawkins et al., 2013; Notter et al., 2010; Majeau-Bettez et al., 2011)
EV battery production represents 30%–50% of EV total lifetime GHG emissions B2U decreases demand for material production, which causes the environmental pollution	(Dunn et al., 2012; Gaines et al., 2011; Gaines and Sullivan, 2010; Zackrisson et al., 2010)
B2U can achieve substantial net reductions in CO_2 emissions because of the potential to be applied in stationary ESS	(Ahmadi et al., 2014b; Cicconi et al., 2012; Genikomsakis et al., 2013)
B2U in stationary ESS connected with renewable energy sources present most environmental benefits (specific benefits depending on specific use case, respective electricity mix and presence of competing technologies	(Casals et al., 2016, 2015; Faria et al., 2014; Sathre et al., 2015)

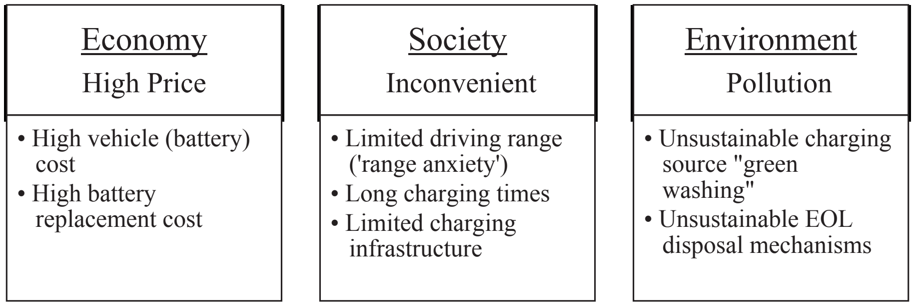

Fig. 5. Unsustainable issues in the EV industry (adapted from Jiao and Evans, 2016a).

lead to a standing element of IB scholars' analytical skills (Poulis and Poulis, 2017). Therefore, given the nature of this interdisciplinary review, it also contributes to opening a major discussion on the identification of the boundary identification in the field of IB.

4. Results

4.1. The rise of electric vehicles: a pressing need for innovative business models

The global automotive industry is on the tip of an automotive revolution towards electric mobility, with recent studies predicting that 54% of new car sales and 33% of the global car fleet will be electric by 2040 (BNEF, 2017). It is estimated that by 2020 the total ownership costs for most EVs will be lower than that of ICEVs, resulting in consumer savings as the lifetime price of purchasing an EV including costs for fuel and maintenance will be lower than that of ICEVs (Renewable Energy Association, 2017). Due to finite available resources, the inevitable shift from ICEVs towards EVs requires new forms of business as the value propositions of e-mobility are more complex (Laurischkat and Viertelhausen, 2017). Furthermore, recent trends such as the sharing economy, moving from owning cars (products) towards using cars (services), will call for increased holistic mobility solutions alongside the inclusion of new stakeholders and their complex interactions that will disrupt current value structures and underline that the whole ecosystem must be re-considered (Kley et al., 2011).

The rise of the sustainable technology of EVs as a potential viable alternative to ICEVs has been accompanied by an expectation that it will bring drastic changes in auto mobility and in new business models, which EV manufacturers and others would need to adapt to enter this market (Wells and Nieuwenhuis, 2015). Researchers argue that a radical shift towards sustainable technologies requires changes to exiting business models, products and social systems and that if companies fail to analyse the whole environment and system of sustainable technologies, it will result in the development of inadequate business models and the loss of competitive advantage (Budde Christensen et al., 2012; Kley et al., 2011).

Further, the sustainable technology of EVs challenges prevailing business models in the presently unsustainable automotive industry, which are heavily dependent on the use of fossil fuels (Bohnsack et al., 2014). This is further supported by Budde Christensen et al. (2012) stating, "… it might be that innovative technologies that have the potential to meet key sustainability targets are not easily introduced by existing business models within a sector, and that only by changes to the business model would such technologies become commercially viable" (p499). Therefore, this would include a reconsideration of the traditional business model concept (value proposition, value creation & delivery and value capture).

A suitable business model can grow the market appeal of a technology such as EVs, improve the value capture of this innovation and finally lead to increased competitive advantage (Chesbrough, 2010). However, in the context of emerging industries and sustainable technologies such as EVs, the right business model is not yet apparent. Bohnsack et al. (2014) emphasizes this stating, "… the emergence of EVs … is a useful context to analyse business model evolution, because this industry is still in the process of discovering a business model that attracts large numbers of customers" (p287). The concept of BMI that puts sustainability at its core is critical for a market uptake of EVs as well as for sources of value creation towards customers that compensates for the higher initial investment cost compared to ICEVs. The mobility concept of B2U could lead to such value creation mechanism through BMI by addressing current unsustainable issues in the EV sector, ultimately making the technology affordable and competitive to ICEVs.

4.2. Unsustainable practices in the electric vehicle industry

Critical issues for a prospective market uptake of EV have emerged. It seems that as a result of highly priced EVs (i.e. high costs of installed LIB packs), there is a heavy burden on the market potential (Bonges and Lusk, 2016). A study by Jiao and Evans (2016a) identified current EV practices and market uptake barriers as unsustainable from the economic, social and environmental perspective (Fig. 5).

From the **economic** perspective, the high price of EVs because of expensive LIB packs is the key barrier for a faster global market adoption. Today, LIB packs in EVs can make up to 30%–50% of total vehicle cost. EVs as a disruptive technology has already been developed but it is insufficient to enter the mass market, which demands low cost vehicles *i.e.* low cost batteries (Lorentz et al., 2015). According to a systematic review study that analysed over 80 different EV LIB pack estimates reported between 2007 and 2014, EV LIB technology has improved significantly in the last decade with battery costs dropping by approximately 14% annually from above $1000/kWh to around $410/kWh (Nykvist and Nilsson, 2015). A study by the U.S. Department of Energy (2017) estimates LIB pack cost between $250/kWh - $300/kWh in 2016. Findings by Bloomberg New Energy Finance (BNEF) found the price of LIB packs at $273/kWh in 2016 and in the case study of a battery production plant in Korea, a price drop to $162/kWh in 2017 and $74/kWh in 2030 is forecasted (Curry, 2017).

Consequently, it must be underlined that the EV industry is still in its infancy stage and to accelerate mass market adoption, the EV market desires an augmentation of capacity and power, increase in the battery's lifetime and most importantly, dramatically reduced battery pack costs to make EVs competitive to ICEVs. Besides available research on present LIB pack costs, there are also a number of recent cost forecasts available for EV batteries in 2020 (Berckmans et al., 2017; P3 Consulting Group, 2016; Pillot, 2015), whereby estimates vary between 250 $/kWh – 131 $/kWh. These are crucial to understand EV LIB market price developments as battery costs need to reach 150 $/kWh, which has been generally comprehended to be the tipping point whereby EV (i.e. battery) technology has become mature and will reach global market penetration (Nykvist and Nilsson, 2015).

EV manufacturers are currently facing trade-offs between final vehicle selling price (price impact of selected battery materials) and desired driving ranges (overall performance of selected battery materials) (Reinhardt et al., 2019). Once the battery is no longer useful for traction purposes and needs to be replaced, customers currently pay high battery replacements cost that represents another economic barrier (Bohnsack, 2013). To tackle these issues, EV companies such as Nissan for its Leaf model and Renault for its Zoe model have started to offer their customers financing options such as to lease only the battery (including warranty and replacement costs) while purchasing the rest of the vehicle (Nissan, 2017b; Renault, 2017b). This can be identified as first indicators of BMI within the EV industry as companies are moving towards product-service systems.

In terms of **societal** perspective, EVs are still seen as inconvenient and have caused so-called 'range anxieties' (limited driving ranges and charging infrastructures) mainly due to current energy density limits of LIB pack technologies. It is commonly agreed that a driving range of around 320 km (200 miles) is sufficient to overcome the fears amongst society and meet average daily driving needs (Nava, 2017). But today, customers must still pay high vehicle prices if they desire a longer driving range (and vice versa).

A further barrier is the EV limited charging infrastructure coupled with long charging times. The frequency, on which EVs need to be charged today, makes the reliability and accessibility of a charging infrastructure critical for wider EV market uptake. Currently, the number of EVs on the road outnumber public available charging points by a six to one ratio, indicating that most EV drivers must currently rely on private charging points (International Energy Agency, 2016). It is therefore important to place public charging points where there is a high concentration of parked vehicles for longer periods of time such as in the workplace, city parking area, shopping malls, airports, and hotels. Although this is not a new finding, the impact of its implementation will be of catalytic influence to develop the market exponentially.

Coupled with the charging infrastructure is the charging time for EVs, which is typically done through alternating current to the EV battery from an external charger ('slow charging') and can take from 4 to 12 h for a full charge (International Renewable Energy Agency, 2017). On the contrary there are fast charging stations ('DC quick charging') that provide a direct current of electricity to the EV battery from an external charger with charging times between 30 min and 2 h for a full charge (Trigg et al., 2013). Fast charging stations are desirable, but they increase battery stress and degradation as well as that for most people, which have charged their vehicles overnight on a slow charger, a fully charged vehicle might be sufficient for their daily average trip needs as mentioned before. To tackle the above mentioned issues, novel business strategies have emerged such as the appearance of the start-up company Better Place that introduced the concept of battery swapping stations, which replaced degraded EV batteries with a fully charged battery of the same type in less than 5 min (Zheng et al., 2014). But the company had to file for bankruptcy in 2012, losing $812 million, mainly caused by the high initial investments needed to set up their business infrastructures coupled with mismanagement issues such as the overestimated market penetration in their pilot study countries. However, the case of Better Place demonstrates again that current prevailing business models and strategies in the EV industry might be considered under new approaches from product-based towards fully service driven (Budde Christensen et al., 2012).

From an **environmental** perspective, there exists criticism that EVs are seen as 'green washing' as most vehicles are charged with non-renewable unsustainable electricity such as from coal (Mariasiu, 2012; Van den Hoed, 2005). Further, there remains a lack of proper EOL EV battery management mechanisms, underlining that sustainable and circular economy approaches such as battery reuse followed by material recycling efforts will become increasingly important (International Energy Agency, 2017). Moreover, a growing EV market will stimulate demand for commodities required for EV battery manufacturing such as lithium or scare and value raw materials such as cobalt. Shankleman (2017) emphasizes on the importance of minimising the environmental impact of such material extraction and monitoring price and availability stating that demand for the EV LIB materials such as nickel and aluminium will both rise to about 327,000 tons a year compared to only 5,000 tons in 2015 and production of lithium, cobalt and manganese will each grow by more than a hundred times.

At this point it can be concluded that secondly using EV batteries in less demanding stationary storage applications may therefore solve current unsustainable issues in the industry, which in turn results in diffusion and competitiveness of EVs on a global scale. However, as discussed in chapter 2, there are also major potential barriers that could impact the success or failure of a prospective B2U market. In synthesizing these findings, the following key potential batteries for B2U have been identified. These are unclear regulatory status, lithium-ion battery price reductions (competition of new and cheap batteries specifically design for energy storage purposes), insufficient availability of second life batteries (as a result of slow market growth), absence of standardised battery testing procedure ('design for B2U'), uncertain battery condition after 1st life in the electric vehicle, high repurposing costs of degraded EV batteries and fire hazards during battery transportation and storage. Nevertheless an in-depth discussion of potential barriers but also opportunities for a prospective B2U market and considering SBM perspectives is not in the scope of this review and shall be further explored in future research.

5. Discussion and implications

5.1. Battery second use market potential

The emerging concept of B2U is a timing topic with substantial market potential (Reinhardt et al., 2017; Fischhaber et al., 2016). A study by Jaffe and Adamson (2014) predict that the global B2U business will accelerate, from $16 million in 2014 to $3 billion in 2035. However, it is difficult to estimate the exact B2U market size as it is strongly dependent on two factors. Firstly on the volumes and type of EV waste batteries to become available for B2U, which is directly linked to the market uptake rate of EVs, and secondly on the future need for storage solutions that is influenced by costs and usability of other storage technologies (Rehme et al., 2016). With regards to the volumes of EOL waste batteries to become available for B2U purposes, it must be underlined that there are no reliable findings on the exact volumes that will be returned. Most EV models have entered the market within the last years and therefore it won't be until 2020-2025 when large volumes of batteries will start to retire.

Available previous studies found that the global annual quantity and weight of EOL LIBs would surpass 25 billion units and 500,000 tons, respectively, in 2020 (Zeng et al., 2012). Standridge and Corneal (2014) estimate in various scenarios that the number of post-vehicle application battery packs eligible for B2U would rise from 1.4 million to 6.8 million by 2035. Regarding the future global battery storage market, a recent study by BNEF (2017) predicts the market to 'double six times' from less than 5 GW-hours (GWh) in 2016 to more than 300 GWh (125 GW capacity) by 2030 while estimating investments in battery storage sectors of $103 billion. A recent study by Reid and Julve (2016) attempted to predict future B2U market size using EV sales forecasts as set out by Bloomberg (2016) and considering average battery sizes between 24 kWh and 64 kWh and secondary life rate of 80% after a 7 year EV in-use phase, forecasts that global EV cumulative sales will reach 6.7 million by 2020 and 88 million by 2030; at the same time cumulative worldwide installed capacity of secondary batteries are predicted to reach 230 GWh in 2025 and an increase by four times to 1000 GWh in 2030 (Reid and Julve, 2016).

5.2. Battery second use: a sustainable business model catalyst?

B2U holds the potential of being incorporated in prospective innovative (sustainable) business models that put sustainable development at its core. But until today, only very few authors have evaluated B2U from a pure market and business model perspective. A study by Klör et al. (2015) evaluated essential economic properties for a potential market for trading second life batteries by distinguishing between basic market designs of an open, closed or intermediary market and concluding that most likely an intermediary-based B2U market will occur whereby an ‘intermediary’ on behalf of an EV manufacturer will be responsible for battery collection, repurposing and finally selling second life batteries to final customers. A study by Rehme et al. (2016) builds upon the open and closed market design as established by Klör et al. (2015) and proposes two concepts: the integrated business model in a closed battery market whereby the OEM implements the B2U process into existing organisational structures through diversification and vertical integration of activities (*e.g.* remaining ownership of batteries), and the multi-agent business model in an open market that allows trading and resale of second life batteries and therefore opens competition among several agents. Similarly, Jiao & Evans (2017) propose a typology of B2U business models that are categorised as standard, collaborative and integrative. Based on these studies and extending their findings, this review presents a conceptual B2U innovative business model framework (Fig. 6). Given the B2U project landscape presented in chapter 1 (Table 1) and previously discussed results, the authors have observed that innovative cross-sector multi-stakeholder relationships are forming to evaluate the full potential of second life batteries in a prospective B2U market.

However, there exists no universal agreement on how LIBs should be regulated as waste. In the case of the United States (US), even though LIB wastes are part of the Environmental Protection Agency (EPA) Universal Waste Rule, they are classified as non-hazardous to the environment due to the absence of toxic elements, such as lead, mercury, or cadmium (EPA, 2019). In the EU on the other hand, EV producers are legally required to take back degraded batteries from their customers, which will be increasing in volumes as EV market share rises (EU directive 66/2006/EC; Winslow et al., 2018). This can be underlined as a driving force that will increasingly bring together cross-sector stakeholders that are interested in the full potential of second life batteries and hence new business opportunities. Such stakeholders are experts on ESS solutions in the energy markets and recycling companies that are interested in closed-loop business model designs that generate new value. This is reflected in the current B2U pilot project landscape as OEMs have entered collaborative joint venture agreements with primarily experts on the energy storage markets (B2U service providers) and the battery recycling industries. But, what remains further clarification by existing legislations is the issue of the re-introduction of used EV batteries (as a new product) in the energy storage markets. This raises a major concern on whether there is a previous transfer of battery ownership and how legislation regulates who is responsible for the battery. This is a critical as there are major technical and safety concerns (*e.g.* fires during battery transportation to repurpose facility/storage) and legislation must be proactive in clarifying producer responsibilities along the entire battery life cycle.

B2U contributes to slowing and closing resource loops as the battery's value is enhanced through increased material and resource efficiency, total service lifetime is extended while distributing the high initial cost among a variety of stakeholders. Thus, the previously considered waste of spent EV batteries is re-used to create new value *e.g.* in the stationary storage markets and the recycling phase is significantly delayed, which has been shown to indicate additional costs and environmental pollution for OEMs. Ultimately, once not useful in specific B2U applications, environmentally sound recycling mechanisms will eventually recirculate recovered materials back into the battery production processes.

This is in conjunction with a study from Bocken et al. (2016a) on product and business model strategies for the circular economy; as B2U slows and closes resource loops it fits within the business model of ‘extending product value’ (i.e. exploiting residual value of products) as “… in this type of business model, remanufacturing typically becomes the activity of the original manufacturer” (p313). But it remains unclear how participating stakeholders in the emerging B2U industry can innovate such strategies into innovative business models. Scholars have recently argued that even though the concept of the circular economy prioritises environmental sustainability and the economic systems (circular models), the social dimensions and objectives are only implicitly addressed and usually absent, which have been previously identified to be a key characteristic of SBMs (key stakeholder to the firm) (Geissdoerfer et al., 2017; Murray et al., 2017; Sauvé et al., 2016). This is supported by Antikainen et al. (2016) emphasizing that there is a lack of frameworks for business model innovation in the context of the circular economy as well as that business models should be comprehended through sustainable value creation for all stakeholders, including the environment and society (i.e. sustainable business models).

Therefore, the concept of business model innovation for sustainability can drive innovation across the entire B2U supply chain whereby value is no longer created by single firms but through collaborative arrangements as indicated by the previously mentioned B2U joint venture agreements. According to Porter and Kramer (2011) such efforts will results in shared value creation that aims to identify and expand the relationships between economic and societal progress through not only innovating products but also markets and activities within the value chain. Building on this and the aforementioned traditional business model concept (chapter 2.2), Bocken et al. (2015) introduce a conceptual framework for a sustainable business model that captures

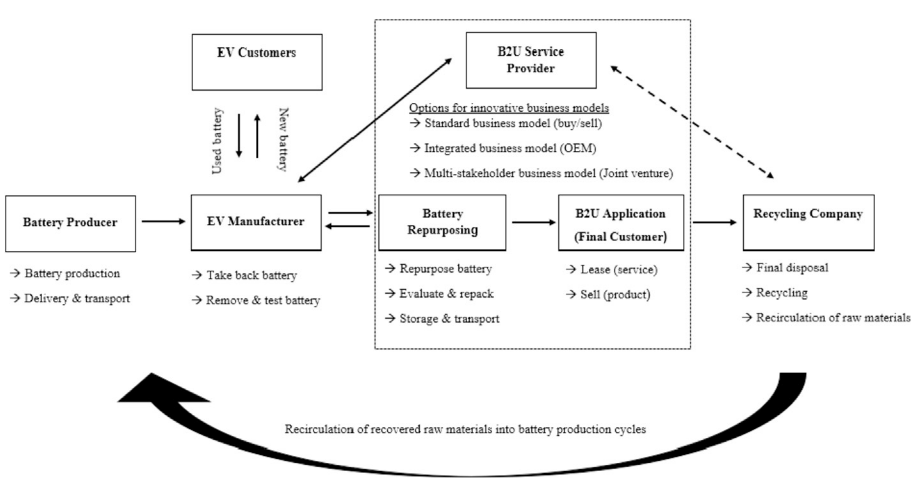

Fig. 6. Conceptual battery second use innovative business model framework.

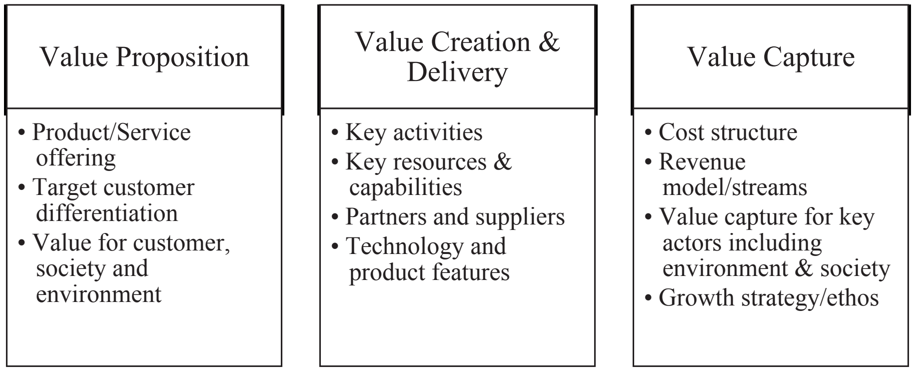

Fig. 7. Conceptual sustainable business model framework (adapted from Bocken et al., 2015).

such value (Fig. 7).

In applying this framework to the concept of B2U, the **value proposition** is focused around exploiting residual value of EV batteries through remanufacturing and reuse and offering customers affordable B2U ESS (through remanufacturing or repurposing). There is further value for customers that use products longer and employees as new jobs are created as part of reuse and recycling activities (i.e. the engagement in an environmentally sound business). The **value creation and delivery** is primarily centred on collaborations (sharing resources, knowledge and expertise) and take-back systems for degraded EV batteries in order to ensure consistent flow of product returns. Lastly, **value is captured** by reducing materials costs (environmental value) while generating new revenue as the economic battery value is increased through B2U in the stationary storage market.

It was further revealed that in considering the previously mentioned SBM archetypes (i.e. generic SBM strategies) the concept of B2U may fit within the environmental innovation type of 'closing resource loops' (remanufacture, reuse, recycle) or 'deliver functionality rather than ownership' (product/service/use oriented product-service systems). In fact, the different archetypical strategies can be combined to form a sustainable business model. However, despite their widely known benefits for the economy, society and environment, successful adaption by industries has not been achieved. This highlights the need for further discussions that address and conceptualise methods and tools that facilitate firms in integrating all aspects of sustainability into the business model innovation process (Despeisse et al., 2017). Thus, this review aims to open up a further dialogue between researchers and practitioners on the topic. It must therefore be underlined that to better comprehend the feasibility of the interconnectivity between B2U and SBMs in theory and practice, follow-up studies are in demand as an incremental shift is needed, triggered by the help of researchers in the field to identify areas for improvement, ultimately making B2U a business case for sustainability.

A further interesting point to raise is whether the presented conceptual SBM B2U system is fundamentally different from other cases where SBM research and concepts have been or might be applied in the future. This is from major importance considering that there is paucity in empirical SBM research that is emphasised by the limited number of case studies and empirical analyses in the field (Evans et al., 2017b). Therefore, one illustrative example is the global sustainability management problem of electronic waste (e-waste) that has arisen as a new sustainability challenge of the 21st century. Ongoing changes in technology and demand have made the global electronic industry the fastest economic growing sector (Puckett et al., 2002). As these products contain large volumes of critical metals, including rare earth elements, couple with the persistent supply risk as a result of limited sourcing in countries, the importance of sustainable material recovery is underlined (Marra et al., 2018). Relatedly, Peñaherrera et al. (2018) propose a conceptual design for a database management system for e-waste within the EU (that tracks e-waste flows and critical metal content) but concluded that participation from producers is unlikely without sufficient economic incentives in place as otherwise such systems are merely seen by producers as an extra administrative burden. Therefore, as major beliefs and concepts of SBMs go beyond sub-categories (*e.g.* circular economy) the SBM system presented in this study could facilitate participating stakeholders in establishing innovative multi-stakeholder relationships to evaluate possible reuse/second use strategies before undergoing current unsustainable disposal mechanisms, ultimately establishing the business case for sustainability within the global electronics industry.

6. Conclusions and contributions

This review argued that the concept of B2U holds the potential to increase the residual value of EV batteries leading towards a faster EV market uptake and improvements of overall sustainability performance through SBM perspectives. However, the available literature remains ambiguous on what SBMs entail as there is a dearth of empirical research and hence more holistic views on the topic are needed. At the same time, the rise of the sustainable technology of EVs with its underlying potential disruptive technology of B2U will challenge prevailing business models in the automotive industry, which has historically been heavily dependent on the use of fossil fuels. This review aimed to address this paucity by offering a fresh interdisciplinary perspective through an investigation of SBM perspectives for the emerging sustainable technology of EVs with a focus on the concept of B2U.

B2U was identified to be a major value creation mechanism for the EV industry. Results indicated that current practices in the EV industry are unsustainable with regards to the presently high EV LIB costs, 'customer anxieties' because of limited driving ranges and charging infrastructures and environmental pollution due to unsustainable charging sources and EOL disposal. It was found that B2U holds the potential to facilitate or even solve these current unsustainable practices in the EV industry. However, the evaluation of the B2U lifecycle stages underlined that key opportunities and challenges remain.

The discussion further revealed that the B2U market potential is strongly dependent on the market uptake of EVs and on the future need for storage solutions. Therefore, there is the potential of an evolving B2U market as increasing volumes of cheap batteries will be taken back to the OEMs in upcoming years that could provide valuable services in ESS. The discussion further found that because of this market potential, OEMs have started pilot projects to comprehend the feasibility and capabilities of B2U. But market developments were found to be still speculative as companies entering this new industry are still evaluating if B2U is a profitable business or not.

Therefore, although B2U business models seem to emerge as a major new way forward for the industry of EVs, the market landscape remains mysterious. It will be several years before first-mass market generation of EV batteries will start to retire, which is directly dependent on the EV market uptake and can be identified as one of the key limitations of this review. However, ongoing B2U projects informed that innovative multi-stakeholder cross-sector relationships between the previously isolated automotive and energy markets are forming that aim to investigate the full potential of second life batteries and hence new business opportunities.

Therefore, a B2U business model framework was conceptualised that addresses these innovative forming stakeholder relationships as well as opens new roads for future discussion among researchers and practitioners. It appears that multi-stakeholder business models are preferred over integrated business models, but further practical rich case studies that take a multi-stakeholder perspective must be carried out to evaluate how OEMs are forming such collaborative agreements to capture to full value of second life batteries. Therefore, it was discovered that prospective B2U business models that take a multi-stakeholder network centric business model design rather than firm-centric one, may prove to be a viable business case for sustainability.

Interestingly, as a result of B2U industrial projects being mainly still in the piloting phases, there is the issue of a dearth of data on identifying all stakeholders that will participate in a prospective B2U market. We are convinced that this is both an important gap but also an exciting opportunity for the market and academia. Therefore, we invite and push for further research on the topic through comprehending attitudes and characteristics of multiple stakeholders that are interested in participating in the emerging B2U market. Moreover, future research should address the different business model relationships that will be established between stakeholders participating in this market, mainly OEMs and B2U service providers, whereby for instance the degree of battery ownership and exchange flow of expertise and knowledge between those stakeholders varies. As a first important step, this review demonstrated that the EV EOL strategy of B2U is a promising way to increase the residual value of the battery that in turn could reduce upfront costs of EVs and lead to a faster global EV market adoption while making the technology itself more sustainable.

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Declaration of interest

The authors report no conflicts of interest.

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