EXPLORING BUSINESS MODELS OF SUSTAINABILITY PIONEERS – AN ANALYSIS OF CASE STUDIES IN THE SMARTPHONE INDUSTRY

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ABSTRACT:

The growing production, consumption and disposal of smartphones is associated with profound social and ecological impacts throughout the product's life cycle. These issues call for a sustainability transformation of the industry potentially initiated by sustainability pioneers, which form the research focus of this multiple case study. A business model for sustainability (BMfS) perspective is taken to allow for a comprehensive description of how sustainability pioneers address the industry's sustainability issues as part of their core business. To this end, business models of 14 sustainability pioneers in the smartphone industry located along the product life cycle are analyzed. This study addresses the lack of empirical studies of the industry's sustainability pioneers and complements the current BMfS discourse with a life cycle perspective. A large variety of BMfS is found within and across the life cycle phases and synthesized into a rationale for each phase. Additionally, the paper discusses the windows of opportunities that the sustainability pioneers' business models are based on.

Keywords: Business models for sustainability, sustainability pioneers, smartphone industry, life cycle

1. INTRODUCTION

Since their market introduction in the late 2000s, smartphones have been supporting increasingly large parts of private, social and business life. The growing production, consumption and disposal of smartphones, however, also have adverse interlinked social and ecological consequences throughout the product's life cycle. Conflict minerals, working conditions in Asian factories and e-waste are infamous examples of the industry's sustainability issues. A full life cycle perspective is needed for a comprehensive image of the interdependent effects of resource extraction, device manufacturing, distribution, usage, and end-of-life treatment (Li, Yang, Lu, & Song, 2015; Moberg et al., 2014).

The unsustainability of the industry is to a large extent shaped by the current business models of companies dominating the market at present. While these companies are highly innovative (Cecere, Corrocher, & Battaglia, 2015), their business models are primarily driven by an economic business logic of selling high numbers of smartphones that are replaced after a short use phase (Boons & Lüdeke-Freund, 2013; Suckling & Lee, 2015). The business model concept, which "allows expressing the business logic of a firm" (Osterwalder & Pigneur, 2010, p. 10), is increasingly used to explain how firms integrate environmental and social concerns into their core business (Bocken, Short, Rana, & Evans, 2014; Stubbs & Cocklin, 2008).

Innovative business models for sustainability with the potential to initiate a much needed sustainability transformation of the smartphone industry are frequently introduced by pioneering new entrants (Schaltegger, Lüdeke-Freund, & Hansen, 2016). Nevertheless, previous investigations in the industry have so far only focused on the exemplary pioneer of Fairphone (Akemu, Whiteman, & Kennedy, 2016; Wernink & Strahl, 2015) or on hypothetical solutions (Bridgens et al., 2017; Suckling & Lee, 2015). This study addresses the research gap how sustainability pioneers address socio-ecological challenges of the smartphone industry along the life cycle through their sustainable business models. Consequently, the following

analysis aims to answer the research question: *How do business models of sustainability pioneers address sustainability challenges along the smartphone life cycle?*

Extending the scope to multiple cases renders a more elaborate picture of how different business models for sustainability shape a more sustainable production-consumption system (Tukker et al., 2008) of smartphones. Understanding the underlying business models of sustainability pioneers can provide guidance for others in the industry in their own sustainability transformation through selection and retention of successful BMfS (Schaltegger, Lüdeke-Freund et al., 2016). The following section discusses how pioneers can contribute to alleviating the sustainability issues of the smartphone industry.

2. SUSTAINABILITY TRANSFORMATION OF THE SMARTPHONE INDUSTRY THROUGH PIONEERS

Smartphone production, consumption and disposal have adverse social and ecological consequences (Bridgens et al., 2017) such as conflict minerals, energy footprint and e-waste (Fitzpatrick, Olivetti, Miller, Roth, & Kirchain, 2015; Greenpeace, 2014; Luo et al., 2011; Moran, McBain, Kanemoto, Lenzen, & Geschke, 2015). Addressing the interlinked socio-ecological challenges requires consideration of all life cycle phases (Li et al., 2015; Moberg et al., 2014).

The following table 1 provides exemplary sustainability issues along the smartphone life cycle (Suckling & Lee, 2015; Suckling & Lee, 2017).

Table 1 Selection of sustainability issues along the life cycle phases based on Suckling and Lee (2015)

Life cycle	Resource extraction and manufacturing	Distribution and network operations	Usage	End-of-life
Sustainability issues	Hazardous or conflict minerals extracted for smartphones (Fitzpatrick et al., 2015; Wu, Chan, Middendorf, Gu, & Zhong, 2008); poor working conditions: harmful practices of mining, extraction and processing (Wilhelm, Hutchins, Mars, & Benoit-Norris, 2015); low living wages, long working hours (Wernink & Strahl, 2015); energy and resource intensive manufacturing processes (Li, Ortiz, Kuczenski, Franklin, & Chong, 2012)	Freight and transport emissions (Moberg et al., 2014); locked-in business models at the point of sales (Boons & Lüdeke-Freund, 2013)	Short use phase varies between 12 month to 3 years on average (Suckling & Lee, 2015); behavior acts as barrier for return, reuse and recycling (Welfens, Nordmann, & Seibt, 2016)	Informal recycling sector for valuable materials, environmental pollution and health problems caused by toxic materials in e-waste (Bridgens et al., 2017; Panambunan-Ferse & Breiter, 2013)

Considering the large sustainability problems of the smartphone industry calls for an industry's transformation towards sustainability (Hockerts & Wüstenhagen, 2010), which can be driven by sustainability pioneers (Schaltegger, Lüdeke-Freund et al., 2016). Sustainability pioneers aim to address and solve specific sustainability problems by identifying sustainability-related market opportunities in a niche (Cohen & Winn, 2007; Hansen & Schaltegger, 2013; Jolink & Niesten, 2015). So-called windows of opportunity (cf. Feola, 2015) emerge when a change in the industry occurs such as the introduction of a novel technology, changing legislations or consumer preferences (Geels, 2005), thus destabilizing existing industry structures (Bidmon & Knab, 2018). These windows of opportunity (Bidmon & Knab, 2018) constitute possibilities for the development of BMfS (Louca & Kokkinaki, 2011) by pioneering companies. Pioneers take advantage of the created windows of opportunity, which enables for the breakthrough of their developed innovations into the mass market (Geels & Schot, 2007). Given their small size, embeddedness in existing unsustainable value chains and higher sustainability standards, pioneers influence other actors such as suppliers within the value chain to embrace

environmental or social issues as well (Hockerts & Wüstenhagen, 2010). They need to grow, multiply, or be replicated in order to transform the mass market (Hockerts & Wüstenhagen, 2010) and gain market share whilst maintaining a high level of sustainability quality. Market incumbents neglect the sustainability niches at first for various reasons, including that niches are not recognized or are not considered to be sufficiently attractive (Schaltegger & Wagner, 2011). Once pioneers have accumulated significant market share, market incumbents often react to competitive threats with sustainability-oriented innovations (Hockerts & Wüstenhagen, 2010). This interaction enables a co-evolution of sustainability pioneers and market incumbents resulting in a substantial sustainability transformation of the industry (Hockerts & Wüstenhagen, 2010; Schaltegger, Lüdeke-Freund et al., 2016). Sustainability-oriented approaches (SA), which can be developed by pioneering companies in the smartphone industry include:

a) S*ocio-ecological effectiveness*, are qualitative sustainability improvements in the way smartphones and services are created and delivered (Young & Tilley, 2006), e.g. through sustainable mining, using conflict-free minerals or Fairtrade practices (Wernink & Strahl, 2015),
b) *Resource efficiency* (Paiano, Lagioia, & Cataldo, 2013) *or narrowing resource loops* (Bocken, Pauw, Bakker, & van der Grinten, 2016) through using fewer and less toxic resources or by consuming less energy per smartphone,
c) *Slowing resource loops* (Bocken et al., 2016) *or sufficiency*, by slowing throughput of smartphones and less frequent replacement (Bocken & Short, 2016; Cooper, 2005),
d) *Closing resource loops* by returning materials to an earlier phase (Bocken et al., 2016), e.g. through recycling (Hobson, Lynch, Lilley, & Smalley, 2018; Welfens et al., 2016)

Literature suggests that combining "greater resource productivity with slower throughput" (Cooper, 2005, p. 58) increases smartphone life spans and reduces the demand for new smartphones and thereby contributes to sustainable consumption (Cooper, 2005) within the smartphone industry. Given the importance of social issues such as conflict minerals, this paper will complement the environmental focus of resource loops with a social sustainability

perspective on smartphones. Based on these approaches, this study analyses how the business models of sustainability pioneers realize socio-ecological sustainability and whether and how the pioneers contribute to a sustainability transformation (Boons & Lüdeke-Freund, 2013; Hansen & Schaltegger, 2013).

3. RELEVANCE OF BUSINESS MODELS FOR SUSTAINABILITY

The business model (BM) concept has been receiving increasing attention since the internet boom of the mid-1990s (Massa, Tucci, & Afuah, 2017). While a large variety of conceptualizations exists (Wirtz, Pistoia, Ullrich, & Göttel, 2016), Osterwalder and Pigneur's (2010) definition is widely accepted, describing business models as the rationale behind an organization's value proposition and value creation, delivery and capture. The following table 2 provides an overview of the constituent components of a business model.

Table 2 Overview of business model components (Based on Osterwalder & Pigneur 2010; Richardson, 2008)

Component	Definition
Value proposition (VP)	The products/services a firm offers to its customers segments and their value to customers. (Entails product/service, customer segments, customer relationships)
Value creation and delivery (VCD)	The system of activities, partners and resources necessary to create and deliver the value proposed to the customer. (Entails key activities, resources, channels, partners)
Value capture (VC)	Describes how revenues are generated from the value proposition and the expenses generated by the system of value creation and delivery. (Entails cost structure, revenues streams)

The business model serves as a useful conceptualization for exploring how a firm addresses the sustainability challenges discussed in section 2 through its core business as the concept integrates key aspects of the creation and consumption of a firm's offers (Boons & Lüdeke-Freund, 2013). Business models for sustainability (BMfS) – also known as sustainable business models – have gained relevance in academic and practitioner communities in recent years (Lüdeke-Freund & Dembek, 2017). To operationalize the concept, Schaltegger, Hansen, and Lüdeke-Freund (2016, p. 6) propose a definition connecting value proposition, creation, delivery and capture (Richardson, 2008) with a sustainability-driven rationale as follows:

> *"A business model for sustainability helps describing, analyzing, 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."*

In more detail, a BMfS supplements a firm-centric view with a multi-stakeholder, systems perspective that integrates social, economic and environmental issues into the firm's purpose (Stubbs & Cocklin, 2008). By acting as market device for sustainability-oriented innovations (Boons & Lüdeke-Freund, 2013), BMfS realize entrepreneurial opportunities mentioned in section 2. Well-performing BMfS can subsequently influence and transform the firm's surrounding business, ecological and societal environment towards sustainability (Abdelkafi & Täuscher, 2016; Lüdeke-Freund, Gold, & Bocken, 2016; Schaltegger, Lüdeke-Freund et al., 2016). This underpins the concept's relevance and utility for analyzing the contribution of a firm to the sustainable development of the smartphone industry.

A variety of BMfS typologies has been proposed in the literature, for instance in the form of eight archetypes – i.e. patterns distinguished by their rationale – synthesized by Bocken et al. (2014). Combining different archetypes may exhibit synergies in unlocking sustainability improvements: For instance, if a company delivers "functionality rather than ownership" (Bocken et al., 2014, p. 50) through a product-service-system (Tukker, 2004), the firm can recirculate products more easily (Hansen, Große-Dunker, & Reichwald, 2009), thus creating "value from waste" (Bocken et al., 2014, p. 49). Consequently, an analysis of sustainability in the smartphone industry from a business model perspective should explore different approaches that appear throughout the life cycle (Chun & Lee, 2013).

Acknowledging sustainability pioneers and their business models as promising subject and unit of analysis, respectively, the following section elaborates on the underlying methodological choices of this study.

4. METHODOLOGY

Business models of sustainability pioneers in the smartphone industry constitute an emerging and complex research field that has not been investigated in depth so far. Therefore, an explorative approach in the form of a multiple case study research design is chosen (Yin, 2014). 14 sustainability pioneers in the European smartphone industry were selected, following theoretical sampling (Eisenhardt, 1989) to cover the entire life-cycle. Each case represents a revelatory case (Eisenhardt & Graebner, 2007) of business models addressing sustainability issues. This makes the overall study more robust with varied empirical evidence (Eisenhardt & Graebner, 2007). In addition, two of the cases cover the entire product life cycle, which together enables replications from case to case and saturation across life cycle phases (Yin, 2014). Only the business areas intersecting with smartphones were regarded for case companies active in multiple industries or product categories. Table 3 gives a brief overview over the selected cases.

Data triangulation aims at strengthening the validity of the study by using multiple measures to corroborate the same finding and hence, avoiding single source bias (Babbie, 2013; Rauter, Jonker, & Baumgartner, 2017). Data was collected from multiple sources (Babbie, 2013), including 14 semi-structured interviews with founders and sustainability or strategic managers of each chosen company conducted between January and May 2018, face-to-face and video interview techniques were applied and each interview lasted between 30 and 45 minutes. The interviews were complemented with secondary data (news outlets, press releases, company reports) and workshop observation with related documentation from a workshop series on sustainable smartphones. The data collection process was documented to increase data

reliability (Yin, 2014). For this purpose, a research file for each company was created, including the recorded and transcribed interviews, collected secondary data, and the researchers' notes made during the interviews. Data collection concluded when a saturation point was reached; the researchers stopped adding additional cases and conducting additional interviews when no new or alternative phenomena and perspectives were observed (Eisenhardt, 1989). A thematic analysis was conducted within and across cases (Eisenhardt, 1989) aiming to search for similar or contrasting results within and across cases (Eisenhardt, 1989; Yin, 2014). The searching and reviewing of themes and patterns within the data set was a hybrid process of deductive, a priori derived codes from literature and data-driven inductive coding (Fereday & Muir-Cochrane, 2006). The collected data for each case was coded and qualitatively analyzed by two researchers to ensure inter-coder reliability (Babbie, 2013). The following table 3 gives a short overview of the cases and interview partners.

Table 3 Overview of case companies and interview partners

Case	Lifecycle phase	Case Description	Country	Interview with
01	Resource extraction & manufacturing	Mining and processing company	Withheld	Project manager conflict minerals
02	Resource extraction & manufacturing	Sustainable smartphone manufacturer	Netherlands	Co-founder and strategic manager
03	Resource extraction & manufacturing	Sustainable smartphone manufacturer	Germany	Co-founder/director
04	Distribution and network operations	Sustainable smartphone reseller	Germany	Co-founder/director
05	Distribution and network operations	Smartphone contract provider	Germany	Co-founder/executive manager
06	Distribution and network operations	Telecommunications company	Switzerland	Corporate sustainability manager
07	Usage	Second-life smartphone purchase and sales company	Germany	Executive strategic manager
08	Usage	Refurbished smartphones platform	France	Co-founder/executive manager
09	Usage	Smartphone repair options platform	Germany	Co-founder/director
10	Usage	Smartphone battery repair shop	Germany	Director/founder
11	Usage	Repair and refurbishing company	Germany	Strategic manager
12	End-of-life	Smartphone take-back/collection company	Germany	Director/founder
13	End-of-life	E-waste collector/recycling consultancy	Germany	Director/co-founder
14	End-of-life	E-waste collector/redistributor	Netherlands	Director/founder

The next sections presents the findings based on the empirical data.

5. PRELIMINARY FINDINGS

The findings within and across cases are presented along the smartphone life cycle phases, the business models are analyzed with regard to the sustainable value propositions, value creation & delivery and value capture as illustrated in table 4.

In the *resource extraction and manufacturing phase,* case company 01 offers certifiable conflict-free and recycled traceable minerals, for use in electronics and production tools manufacturing. Rather than avoiding conflict-ridden areas altogether, the case companies (01-03) seek to contribute to sustainable development by dedicating large efforts to analyzing and developing their supply chains, particularly the areas of fairer mining and manufacturing. The manufacturers (cases 02, 03) make use of the leeway they possess in improving the sustainability of smartphone production and consumption by exerting influence over the entire life cycle. By deploying a modular and durable design and longer-term product strategy, device lifetime and circularity are improved (02, 03). Furthermore, cases 02 and 03 emphasize open customer relationships by providing support, updates and repair services. Furthermore, the companies set incentives for customers to return their products and either recirculate them or prepare their recycling (02, 03).

Within the *distribution and network operating phase*, companies offer more sustainable smartphones (04, 06), or advocate for sufficiency to keep their own smartphones as long as possible (05). Companies in this phase offer smartphones produced under ecologically sound and fairer conditions available on the market (04, 06), spare parts for smartphone repair (04) or network contracts with integrated monthly donations for socio-ecological projects (05). Moreover, the pioneers' partner networks in the manufacturing, usage and end-of-life phases allow them to support consumers in selecting sustainability-oriented products and prolonging the smartphone's usage phase. Improving the underlying processes towards climate neutral

logistics (04) or energy efficient network operations (06) are different paths taken towards sustainable consumption in this life cycle phase.

Five cases within the smartphone *usage phase* offer different business models for slowing (08-11) or closing (11) of resource loops through repair (09, 10), refurbishment (07, 08, 11), resale (07, 08, 11) or take-back (07, 11). All case companies address varying requirements of ecological treatment of defect or disused smartphones - with case 11 also integrating the social perspective - through economically viable business models. The business models of cases 08 and 09 are particularly interesting since their represent multi-sided platforms linking consumers to refurbishers (08) and repair shops (09).

The *end-of-life phase* is characterized by companies that mainly address the e-waste issue. The cases fill a niche for smartphone take-back and preparation for recycling and thus, slowing and closing the loop between consumers and recycling companies. Thereby, companies either focus on consumers and companies in the global North as a result of regulations related to e-waste recycling (12, 13) or the global South due to its increasing piles of e-waste (14). Their business models' value propositions are advertisement space (12), regulatory compliance (13) or corporate social responsibility through e-waste footprint offsetting (14). These business models address the e-waste issue whilst offering various services at the same time, which together forms the core of the economic rationale of the company.

Table 4 Business model attributes for the four sustainability approaches along the smartphone life cycle

	Resource extraction and manufacturing (cases 01-03)	**Distribution and network operations (cases 04-06)**
A) Socio-ecological effectiveness	VP: Conflict-free traceable minerals (01) Fairer and transparent extraction and production (01-03) Abstaining from conflict minerals (01-03)	VP: Mobile contract with Fairphone (06) or integrated donation/"painless giving" (05) Reselling sustainably-produced smartphones, (04)
	VCD: Supply chain development (01-03) Company-owned audited production (03)/mine (01) Cross-sectoral partner network (01-03) Sustainability communication (02-03) Documentation and certification for due diligence (01)	VCD: Climate neutral forward and reverse logistics (04) Direct manufacturer cooperation (04) Branded reseller of network operator's network capacities (05) Donation partners (05)
	VC: Market-based commodity prices (01) Phone sales using cost-based pricing (02-03)	VC: Network contract fees (05-06) Phone sales (04)
B) Resource efficiency	VP: /	VP: /
	VCD: /	VCD: Own or partner energy-efficient telecommunications network (05-06)
	VC: /	VC: Network contract fees (05-06)
C) Slowing loops	VP: Modular smartphones for longevity (02-03) and upgradeability (02) Spare (02-03) and upgrade parts (02) Upgrade (03) and repair services (02-03) Organizing device recirculation (02-03)	VP: Mobile contract consciously not including smartphone (05) Reselling spare/upgrade parts and accessories (04) Repair and take-back services (04, 06)
	VCD: Supply chain development (02-03) Cross-sectoral partner network (01-03) Sustainability communication (02-03) Long-term product strategy around modular platform (02-03)	VCD: Sustainability communication and advocacy for sufficiency (05) Climate neutral forward and reverse logistics (04) Direct manufacturer cooperation (04) Branded reseller of network operator's network capacities (05) Store/online collection & repair infrastructure (06)
	VC: Spare (02-3)/upgrade (02) part sales using cost-based pricing (02-03)	VC: Network contract fees (06) Spare/upgrade parts and accessories sales (04)
D) Closing loops	VP: Recycled minerals (01) Modular smartphones for circularity (02-03) Organizing device recycling (02-03)	VP: Take-back services (04, 05)
	VCD: Supply chain development (02-03) Cross-sectoral partner network (01-03) Sustainability communication (02-03) Long-term product strategy around modular platform (02-03) End-of-life handling (02-03) Smelting/recycling homogenous materials (01)	VCD: Climate neutral forward and reverse logistics (04) Direct manufacturer cooperation (04, 06) Store/online collection infrastructure and recycling partners (06)
	VC: Market-based commodity prices (01)	VC: Network contract fees (06)

Table 4 (continued) Business model attributes for the four sustainability approaches along the smartphone life cycle

	Usage (cases 07-11)	End-of-life (cases 12-14)
A)	VP: Integration of people with disabilities into workforce (11)	VP: /
	VCD: Adjusted HR practices (11)	VCD: /
	VC: /	VC: /
B)	VP: /	VP: /
	VCD: /	VCD: /
	VC: /	VC: /
C) **Slowing loops**	VP: Buying back disused devices C2B (07) or B2B (11) Selling second-life smartphones (07-08, 11) at different refurbishment/price grades and secured by extended warranty (07-08) Offering spare parts and repair tutorials (09) Multi-sided platform for second-hand smartphones (08) or comparison of repair options (09) providing a level playing field for transactions (08-09) Battery replacement service (10) Certified data deletion and CSR-data on footprint reduction (11)	VP: Collection boxes with user rewards (12) Advertisement space (12)
	VCD: Grading system for device acquisition (07, 11) Refurbishment (07, 11) based on cost-benefit-calculation (07) Sourcing of spare parts from third parties (08) or device cannibalization (07, 11) Feedback for continuous refurbisher improvement (08) User review system (08-09) Developing repair tutorials (09) Repair skills and activities (07-11) Reverse logistics (07, 11)	VCD: Own collection of smartphones (12)
	VC: Product (07) or part (09) sales with dynamic pricing (07) Commissions on sales (08) or number of enquiries (09) Price dependent on repair (10) or on residual value of device minus data deletion fee (11)	VC: Advertisement/service fees (12)
D) **Closing loops**	VP: Taking back disused devices as B2B service (11) Certified data deletion, recycling and CSR-data on footprint reduction (11)	VP: Collection boxes with user rewards (12) Advertisement space (12) ElektroG-compliance service for companies' waste-related product responsibility (12-13) E-waste handling and recycling redistribution in poor (14) or industrialized (12-13) countries Offsetting electronic waste footprint for companies (14)
	VCD: Reverse logistics (11) Device preparation for recycling (11)	VCD: Partner network for device take-back (13) and recycling (12-14) Own collection of smartphones (12, 14) Consultation on e-waste legal implementation (13)
	VC: Pricing dependent on residual value of device minus data deletion fee (11)	VC: Advertisement/service fees (12) Purchases and sales of e-waste (14) Differentiated price per weight (13) or fixed rate for service (13) Compensation price for material offsetting (14)

Overall, the findings reveal that a variety of pioneering companies addresses sustainability issues in the smartphone industry. BMfS of pioneering companies are characterized by unique and distinct features found in single cases, as well as similarities across cases. Thereby, they have developed BMfS, which are novel to the industry and contribute to sustainable development within one life cycle phase and across life cycle phases.

6. DISCUSSION AND CONCLUSION

The analysis of this study yielded a large variety of business model designs within and across the life cycle phases. Despite this variety, it is possible to synthesize an underlying rationale (Osterwalder & Pigneur, 2010) for the pioneers' business models of each phase, which exhibit overlap with many suggestions from academic literature:

- Resource extraction and manufacturing: Develop the supply chain towards sustainability, make use of socio-ecologically effective design (Hankammer, Jiang, Kleer, & Schymanietz, 2017; similar to Wernink & Strahl, 2015) and organize product recovery.
- Distribution and network operations: Enable sustainable consumption via provision of more sustainable devices and services or sufficiency by promoting alternatives to the purchase of a new device (similar to Bocken & Short, 2016; Cooper, 2005).
- Usage: Offer different pathways for slowing resource loops (similar to Bocken et al., 2016) by prolonging the device lifetime either in its first use phase or in additional use phases.
- End-of-life: Create economically viable ways to incentivize and organize e-waste collection and flow to appropriate recycling facilities to recover valuable materials, thus closing resource loops (similar to Bocken et al., 2016; Welfens et al., 2016).

While these rationales may appear distinct from each other, they remain inherently linked, which supports the life cycle perspective taken by this study and many other authors (e.g. Frey, Harrison, & Billett, 2006; Suckling & Lee, 2015; Welfens et al., 2016). Business model choices within one phase have profound influence on the options in later phases. The most important pioneers in this regard are – unsurprisingly – smartphone manufacturers, as they exert control over sustainability of production and design. This study confirmed that embedding modularity and openness in the latter is a decisive factor in ensuring a long product life in the usage phase

and recyclability at the end-of-life (Bridgens et al., 2017; Hankammer et al., 2017). While the manufacturers are reaching into every LC phase, they still rely on a network of partners, particularly in their own supply chain as well as for distribution and eventual closing of resource loops. Despite this – and contrary to the suggestions of inter alia Bridgens et al. (2017) and Hobson et al. (2018) – the manufacturers were not able or willing to implement a product-service-system BMfS for their devices, yet. This can be explained by capital requirements being a potential barrier (Tukker, 2004) and the pioneers' emphasis on strengthening the connection between customer and device. Case 02, however, is currently piloting a B2B-PSS. Continuing, resource efficiency was not emphasized by the pioneers, possibly because of the miniaturization and subsequent material savings inherent in the design of smartphone (Paiano et al., 2013). Due to their location in the life cycle, the pioneers in the usage and end-of-life phases are focusing on mitigating the unsustainability of the significantly larger market of conventional smartphones. The connection to the conventional market explains the larger numbers of pioneers in the usage phase (Riisgaard, Mosgaard, & Zacho, 2016), compared to other phases. This is also reflected by the multi-sided platforms of cases 08 and 09, which rely on network effects and thus large numbers of consumers and refurbishers or repair shops to begin with (Parker & van Alstyne, 2005).

Pioneers take advantage of three windows of opportunity, which are created by various external factors in different phases of the life cycle. Firstly, BMfS of pioneers in the sustainable extraction and manufacturing phase take advantage of increasing demand for sustainable alternatives in society (Schaltegger & Wagner, 2011). They innovate and experiment with product designs and business practices, pushing sustainability performance requirements further (Hockerts & Wüstenhagen, 2010). Secondly, another window is created by the dominating incumbents with their demand-increasing mass market business models (Hockerts & Wüstenhagen, 2010). This study found that these windows are constituted by the high

residual value in smartphones left uncaptured by incumbents (cf. Yang, Evans, Vladimirova, & Rana, 2017), which is captured by pioneers in the distribution and usage phase through the slowing or closing of resource loops (Hobson et al., 2018). Pioneers notice that offering repair of smartphones or reselling used ones for a reasonable price is a feasible business with increasing customer numbers (cf. Riisgaard et al., 2016). This underscores the consumer analysis of Mugge, Jockin, and Bocken (2017), but also indicates that the pioneers have already found feasible business models for refurbishing and reselling smartphones. However, the acquisition of original spare parts and the legal impediments connected to original components (e.g. warranty) is a bottleneck for companies when closing loops (Riisgaard et al., 2016). Academic literature suggests that market incumbents react to competitive threats of pioneering companies (cf. Hockerts & Wüstenhagen, 2010) by copying and modifying the pioneering business models (Schaltegger, Lüdeke-Freund et al., 2016). Thereby, incumbents pursue lucrative market opportunities (Schaltegger, Lüdeke-Freund et al., 2016) with own repairable design, repair services, original spare parts or second-hand offers. This observation could also be made through the interviewees' answers and related secondary data sources (Watson et al., 2017). Furthermore, if modular designs and open access to spare parts and tutorials (Hankammer et al., 2017) were to become mainstream in the mass market, the demand for specialized repair skills as offered by pioneers in the usage phase could drastically decrease. Building on the finding that the BM choices across LC phases are linked, the business models of repair pioneers occupy a different niche than sustainable manufacturers, which is potentially threatened by the latter's market success. Due to the above-mentioned possible changes in the sustainability landscape, BMfS of pioneering companies in the usage phase, which currently mitigate unsustainability and adapt their BMfS to dominant incumbents' offers, may become obsolete. Thirdly, another window of opportunity was created by the European Union's environmental legislations, WEEE (Waste Electrical and Electronic Equipment) directive and its national implementations. BMfS of pioneers in the end-of-life phase offer compliance-based

services and create necessary infrastructures for collection and recycling, hence, increasing smartphone return and recycling rates (e.g. Welfens et al., 2016). Thereby, pioneers offer complementary counterparts (Hockerts & Wüstenhagen, 2010) to the existing business models of incumbents and together contributing to a sustainable development within the ICT industry.

In conclusion, there is a variety of BMfS through which sustainability pioneers in the smartphone industry can contribute to the solution of the industry's sustainability issues. While manufacturers are key actors in transforming the production of smartphones towards sustainability, pioneers in the usage and end-of-life play an important role in decreasing primary consumption in the first place and recovering precious materials. It is only together that the BMfS of the analyzed pioneers form a more sustainable system of smartphone production, consumption and recycling. Since the transformation of the smartphone industry is still in its infancy, future studies may explore whether and how sustainability pioneers will have triggered change of incumbents' business models, as hinted at by the sustainability-oriented innovations of mass-market manufacturer Apple (Greenpeace, 2017). Additionally, the introduction of PSS by manufacturers to improve the circularity of devices remains an interesting and current topic.

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