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## Strengthening Industrial Ecology's Links with Business Studies: Insights and Potential Contributions from the Innovation and Business Models Literature

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**Abstract:** The declining availability of natural resources and the environmental impacts of continued extraction of primary resources for production activities have forced greater focus on waste streams and recycling activities. Industrial ecology as a field of practice and theory has been closely related to sustainability issues, yet despite the development of much theory and specific tools and methodologies, the link between natural, industrial and economic systems is not convincing. Not only that, the need for delivering sustainable production and consumption practices is increasing, which is demanding new solutions to existing problems, particularly around the degree of novelty. The interaction of industrial ecology with business studies and industrial investment decision-making remains under-developed, and this is likely impacting on the adoption of more sustainable and resource-efficient practices. As such, this paper uses a constructive approach and explores how two areas of the literature can support the development of the industrial ecology field into strategic business practice: firstly, the innovation literature, particularly the emerging work on open innovation and sustainable innovation as a model to understand radical innovation processes and the creation and maintenance of networked systems of firms; secondly, the closely related area of business model (BM) innovation, specifically the emerging typologies of sustainable BMs and how these typologies can be developed and used as a route to positioning recycling activities at the strategic management level of the firm.

**Keywords:** industrial ecology; product-centric recycling; open innovation; sustainable innovation; business models (BMs)

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## 1. Introduction

The recognition that we live in a world with limited resources is driving activities towards increased sustainability. Sustainability has been generally defined as the ability for the current generation to live life that does not come at the expense of future generations living theirs. Whilst sustainability, or rather, the need to avoid unsustainable activities, has been a challenge for a number of decades now, it is increasingly being addressed with greater urgency. As the need for delivering increasingly sustainable production and consumption practices increases, this is changing the type of solution required, particularly around the degree of novelty. In order for us to become more sustainable in a relatively short period of time, changes need to be radical in orientation and involve whole product architectures or system changes. In this sense, sustainability is driving an increased acknowledgement of the need for innovation, particularly radical innovation, even if this translation into actual innovative activity is not yet evident.

This special issue “Wealth from Waste: Urban Metal Resources and Industrial Ecology” deals with one of the core aspects of sustainability: increasing the resource efficiency of materials and metals through re-use and recycling in our production and consumption systems. The declining availability of natural resources and the environmental impacts of continued extraction of primary resources for production activities have forced greater focus on waste streams and recycling activities. Recycling activities have become increasingly complex and integrated in recent years, corresponding with the greater sophistication of industrial production activities and consumer goods.

The increasing sophistication of recycling processes requires collaboration and network linkages across disparate components of industrial activities. Value and supply chains are changing their orientation from linear chains to networked systems. Just as innovation activities have become pivotal to production and consumption activities, they are also essential for recycling activities. Re-use and recycling of materials and metals will require fundamental innovation within and realignment of supply and value chains, which, in turn, are an integral part of a business model (BM). One of the clear opportunities for sustainable BMs is in the area of waste management and the treatment of waste products as valuable. BMs that move waste streams from having no value or increasingly seen as a cost in terms of management and disposal, to treating waste streams as valuable resources are a clear business opportunity. Although, in order to access these new “above-ground” material resources, product, product systems, supply chains and generally how businesses do business will need to change.

Industrial ecology is a field of practice and theory that has devoted significant attention to understanding the materials and energy flows of our production and consumption systems, with a special focus on understanding the impacts of our industrial system on the environment, our stocks of resources and the losses associated with waste and disposal [1–3]. The link between industrial ecology and sustainability was made early, with it being referred to as the “science of sustainability” [4]. Despite the development of much theory and specific tools and methodologies (e.g., Life Cycle

Assessment and Material Flow Analysis) the link between natural, industrial and economic systems is not convincing, particularly the link to economic systems. Industrial ecology has long emphasized the technological aspects of the field, but has lacked the social/soft system changes required for the adoption of new technologies and practices. The interaction of industrial ecology with business studies and industrial investment decision-making remains under-developed [5–8], and this is likely impacting on the adoption of more sustainable and resource-efficient practices.

This special issue set out six themes for investigation in understanding the opportunities to derive value from recycling above-ground resources. This paper contributes to the theme on mapping out the innovation and BMs needed to create and capture resource value in future value chains. This paper uses a constructive approach to examine how two areas of literature can be used to support the development of the industrial ecology field into strategic business practice and provides for new solutions for BMs to support resource efficient practices. The first of these areas is found in the innovation literature, particularly the emerging work on open innovation and sustainable innovation as a model to understand radical innovation processes and the creation and maintenance of networked systems of firms. The second and closely related area is that of BM innovation. The focus here is on the emerging typologies of sustainable BMs and analysing how these typologies can be developed and used as a route to positioning recycling activities at the strategic management level of the firm, with the ultimate aim of understanding how recycling activities can be increased in the industrial system.

### *1.1. Major Changes Required for Increasing Recycling Activities*

A recent United Nations Environmental Programme (UNEP) report from the International Resources Panel (IRP) outlined the ambition that recycling activities move away from material centric approaches, where recycling opportunities are considered on a material by material basis, without acknowledgment of the context of that material when it comes to be recycled and, instead, that recycling activities move to a product-centric approach, which seeks opportunities for recycling all materials within a product [9]. For example, mobile phones can contain more than 40 elements, including base metals, such as copper and tin, special metals, such as cobalt, indium and antimony, and precious and platinum group metals, including silver, gold, palladium, tungsten and yttrium [9].

The product-centric approach deals with the product as a whole rather than as separate contained metals and materials and is seen as a more appropriate description to closed-loop cycles [5], as, arguably, loops can never become totally closed (*i.e.*, without any loss of resources). The closed-loop analysis is nevertheless considered a useful analogy for communication about the ambition of recycling activities, and the term is used as such in this paper.

The economics of recycling is one of the key limitations preventing the adoption of more recycling. There is a supply and demand mismatch, in that for some metals and materials that are valuable, or rare (or both), recycling is viable, but for the majority of the volume of materials that could be recycled, this is not the case. This situation undermines the product-centric approach and incentivizes the recycling of specific materials regardless of their location with other materials. This is where innovation and, most likely, radical innovations in products, services and BMs are needed to structure and incentivise a wider group of stakeholders and economic actors to investigate the potential for value creation in both the high value/low volume materials, but also the high volume/lower value materials.

The same report [5] identified three major changes required to increase and accelerate metal recycling, including:

1. Focus on optimizing the recycling of entire products at the end-of-life instead of focusing on the individual materials contained in them;
2. Increasing the role of the manufacturing industry in the design of products that facilitate recycling, leading to a substantial increase in recycling efficiency; and
3. Increased education and requirements for consumer participation in disposing of waste at appropriate collection points [9].

In each of these three major changes, technological challenges are evident, but more prominent are the system-level innovation required to incentivise a wider group of stakeholders, including producers and manufacturers, customers, policy makers and regulators and end consumers, to generate and adopt the changes required.

Networked or closed-loop supply chains are rarely considered as value-creating systems in the strategic sense, but rather the focus is the operational issues [10]. Moving to such BMs will require firms to have a deep understand of their business practices and the benefits of these practices and to cultivate more sophisticated relationships with key stakeholders, such as customers, suppliers and partners [7]. “Open” BMs have been analysed for innovative activity [11–13], and this literature shows the challenges of developing BMs that support the creation and maintenance of such complex business networks, whilst, at the same time, providing value creation and capturing opportunities that make them viable for firms to engage in.

This makes the open innovation literature highly relevant in understanding how industrial ecology and business studies can bridge the gaps between technological and operational issues of recycling and strategic decision-making. It also highlights the integral role of BMs in operationalizing and coordinating value creation when value is determined by the action of more than one firm. BMs have been integral to trading and economic behaviour since pre-classical times [14]. They are defined as the firm’s way of organising itself, “how firms do” business, as well as how they operationalize firm activities and organisational routines, as well as explaining “how value is appropriated”, not just how it is created.

### *1.2. The Constructive Approach*

The constructive approach is a research procedure for producing constructions. Constructions are proposals for solutions to explicit real-world problems with reference to accumulated theoretical knowledge. Two important characteristics of constructions are that they are both useable and can be demonstrated through implementation and novelty [15]. Constructions are, therefore, proposed solutions to a practical problem that are built from the identification and understanding of the problem and analysis of the theoretical connections to the problem. The solution needs to have both practical functioning, as well as contributions back to theory.

The constructive approach has been used in many fields of research, including technical studies, clinical medicine and operations research, but has thus far been underutilized in management studies, despite the ability of the approach to offer sound, evidence-based solutions to management problems [15].

This paper develops a constructive approach to the problem of the need to increase product-centric recycling, by analysing the theoretical and conceptual basis of two areas of both relevant, but novel, in an effort to develop a solution to this problem. This study uses the constructive approach, but is not a constructive study in itself, consistent with Callen [16] and Kellett and Sweeting [17]. The aim here is to not solve problems, but to observe and analyse what others have done either in research or in practice in the field of open innovation, sustainable innovation and BM innovation to support the development of the industrial ecology field into strategic business practice with the aim of supporting resource-efficient practices.

### *1.3. Context for This Research*

This work is part of a new research cluster funded by Australia's premiere public science organisation, the Commonwealth Scientific Industrial Research Organization (CSIRO), to investigate alternate scenarios for Australia's mineral wealth and sources of future global competitiveness. Australia is a country heavily reliant on the extraction and exploitation of its below-ground resources in metals and ores. The country also faces unique challenges in terms of recycling scale and infrastructure, with a large land mass and (relatively) small and geographically-dispersed population, providing low economies of scale on the basis of the currently available infrastructure.

Transitioning to accessing and valuing above-ground resources represents both an immense challenge in developing the ability to overcome the status quo and an opportunity, in the sense that the ability to understand and adopt practices that value above-ground stocks provides both a continuing opportunity for resources to play a role in the Australian economy, but also in developing innovations and systems that an increasing proportion of the globe is also going to want to access in the coming decades, as a new source of competitive advantage.

This paper has four sections, including this Introduction. The following section discusses the key characteristics of innovation, including defining open and sustainable innovation. The third section discusses BMs, what they mean and which of the range of emerging typologies of sustainable BMs may be suitable to operationalizing greater recycling activities in closed or semi-closed system scenarios. The final section highlights where the gaps in our knowledge exist, how the constructive approach was beneficial and where future research is required.

## **2. Innovation in Firms**

### *2.1. The Organisation of Innovation*

In terms of innovation, the Organisation for Economic Co-operation and Development (OECD) definition is most frequently cited and used in the data collection of most major countries. Innovation is defined as the implementation of a new or significantly improved product (good or service), process, new marketing method or a new organisational method in business practices, workplace organisation or external relations [18]. Increasing industrial recycling rates will require innovation in all of these areas. Innovation is a broad concept encompassing the inception and creation of new products, reducing costs of producing existing products and adopting new business practices or management techniques.

Innovations have three primary elements. First, that innovation is something new, whether completely new or, as is more likely the case, a recombination of previous knowledge to create significant improvements to existing products and processes. Second, innovation can occur in a number of spheres, not just in relation to new products, but also new processes, both operational and organisational. Third, that innovation includes activities that are external to the actual innovating agent. In recycling activities, this third element will be very prominent, as successful innovation will require innovative activities to be coordinated across supply and product links up and down the value chain.

The success of an innovation is usually defined in economic terms at the point of exchange: did someone actually buy the new product or service for a cost higher than the value of creation? The exchange relationships have also focused innovation research on the demand-side drivers for innovative activity, including what are users' needs and how do future uses of the innovation shape and nurture the early innovation process.

As innovation is such a broad and all-encompassing term, numerous categorizations have emerged to refine the concept. Product innovation can be further classified into goods and services and process innovations into technological processes and organisational processes [19]. Further categorisations can also be made regarding the source of demand for individual innovations in the production cycle, these being investment products, intermediate products and consumer products. Sectoral factors offer further classifications in manufacturing regarding the sectoral use of technology, with divisions being made between high-, medium- or low-usage sectors, and service sectors being categorised according to their knowledge intensity [19,20].

The role of innovation in the design of new products and services and the productivity gains achieved through technological process innovations are well established. A more recent realization is the role of organisational and managerial process innovations. These processes relate to the managerial or organisational "strategies, structures or routines of a business, which aim to improve the performance of the business" ([21], p. 58) Examples include changed corporate directions, implementation of advanced management techniques, such as Total Quality Management, improved business performance measures, significant workplace re-organizations and important changes to communication and information networks. Organisational innovations are themselves an important source of productivity growth, but have also been shown to be closely related to the successful implementation of other innovations, both product and technological processes [19].

The distinction between types of innovation is important, because of the breadth of activity and behaviour that encompasses innovative activity. Different innovation types are associated with differing behaviours and actors. Innovations can also require a composition of different types of activities for successful execution. This combining of types of activities is evident in a firm's BM, which will include technological aspects of a firm's strategy, but also market contact and development activities, financing and revenue models, product delivery and the sourcing and treatment of inputs and outputs for the production process. This is covered in further detail in Section 3.

## 2.2. *The Novelty of Innovation*

A further categorisation of innovation is available through the novelty of innovation. The terms radical and incremental innovation have usually come to be attached to the technological component of

innovative products and services, but increasingly, as we begin to speak of innovations that involve the organisation of the production and consumption systems, we start talking about innovations requiring socio-technical system-wide innovations to be successful. For example, Apple's iPod™ is considered a technological innovation, but the creation of iTunes, the new purchasing systems for music and the new revenue model of single song purchase (rather than whole album purchases, as previously) led to the disruptive and radical changes the iPod™ created in both personal music device markets, but also in the music recording industry.

The definition of innovation has a requirement for “newness”, but it is the extent of this “newness” that distinguishes radical innovation. Radical innovation is assessed at three levels: new to the firm, new to the country and new to the world [22–24]. It is also associated with disruptive effects for both customers and manufacturers. These innovations are often the result of a much larger group of researchers, scientists and specialists across multiple organisations, both public and private. They are also unlikely to have lead users or internal champions and, therefore, struggle to develop the essential feedback loops needed for successful exploitation. On the positive side, radical innovation is associated with irreversible industrial change, new phenomena and the potential for new industrial creation and the resulting employment and export growth of these new industries.

Understandably, the pathway to success for radical innovations is often longer and more complex than for incremental innovations. This is largely due to uncertainty, and a series of “unknowns” exist: how and when these discoveries will transfer into applications is unknown [25], as is how they will change industrial composition and competitiveness [26] and who will benefit from any resulting wealth creation [27]? The functions and advantages of radical innovations are unfamiliar to customers [28], as market feedback in the early stages of the commercialisation of these innovations is not available to guide the commercialisation process in the same way as exhibited in other areas of new product and service development. This can result in mismatched technology and market development, which is a further risk to the innovation process.

### 2.3. *Open Models of Innovation*

Open innovation has gained rapid prominence in innovation studies in the last few years as a way of describing an alternative innovation trajectory to the more established closed innovation model. The closed model of innovation is where firms research and develop innovations and then market and sell the resultant new products and services. Chesborough [29] coined the phrase “open innovation” after analysing the innovative activities of Xerox and other U.S.-based multi-nationals. He used the term open innovation to describe “a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology. Open innovation combines internal and external ideas into architectures and systems whose requirements are defined by a business model.” ([29], p. xxiv).

Firms and their innovation process have always been open to some extent [30–32]. Innovation surveys globally and analysis of innovation practice over decades has highlighted the importance of supply chains and competitors to a firm's innovative activity. Where the open innovation model differs is that it places the systematic exploitation of external sources for innovation as critical to the innovation process, and it shifts the emphasis of the key process from sourcing ideas into the firm, to

focusing on the process within the firm of re-combining externally sourced ideas with internal knowledge and know-how into value [29,33].

The importance of innovation networks as sources of knowledge and as drivers for the innovation process is relevant from a closed-loop/industrial ecology perspective, in that similar “open” networks are required to identify opportunities and drive the integration of recycling processes into the wider production processes. The shift from an internal to an external focus on knowledge and idea sourcing as highlighted in open innovation could also be expanded to the sourcing of other resources, such as inputs, design and production processes.

The model has emerged as a response to two factors: first, the changing innovation structures within firms, who, with the decreasing lifetimes of products, are less willing to take on the risks and costs of the whole innovation process enclosed within the firm; second, the open innovation model has emerged as a mechanism to cope with global information flows.

The dominant risk of innovative firms, particularly firms involved in commercializing radical or new technology innovations, is that they will be unable to capture the full value of their innovative activity. Innovation systems theory, in fact, counts on the availability of innovation spillovers or externalities being available to other firms [30,34–36] and regional innovation systems theory and cluster policy building on the geographical constraints or stickiness of these externalities [37]. Open innovation makes explicit an implicitly occurring process and, by drawing it into the innovation strategy of the firm, allows these firms to have some control over the process and its outcomes, and divest themselves of some of the risk of innovating in a traditional closed model [38].

Similar risks associated with radical innovation will also exist in closed-loop processes, the opportunity for knowledge-sharing and process improvements, particularly when this is informed by users, is of great intangible value to firms seeking to introduce new products, processes and services in this area. These benefits can go some way toward mitigating the risks associated with radical change.

The open innovation literature does not have all the answers; it is still an emerging concept. Research to date has largely focused on external innovation sourcing, the determinants of these sources [29,38] and the impact of these innovative activities on firm performance [39,40]. Studies have also primarily been confined to the analysis of large firms and high-technology industries; although recently, attention has turned to the applicability of the open innovation model to small and medium-sized enterprises [40,41] and in less technology-intensive industries [42,43].

Unfortunately, and critically, the ways in which open innovation creates internal value for the individual firms has largely been left unexplored: “... the link between innovation inputs and outputs and the efficiency of this process has become a black box rarely opened up by systematic research” ([33], in p. 512). An open innovation model, however, could alleviate some of these challenges by building customer contact into the innovation process, as it formalizes the external idea search and acquisition process and therefore could offer formal pathways to customers and markets earlier in the innovation process.

#### *2.4. Defining Sustainable Innovations*

Research on sustainable innovation has expanded rapidly in the past decade; however, the term remains loosely defined. The most widely used definition of sustainability is the one defined by the

Brundtland Commission in their report, *Our Common Future*, where sustainable development is defined as "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs" ([44], p. 37). This definition has then been appropriated to refer other aspects of sustainability. Other authors refer to intergeneration equity in the balancing of current and future ecological demands. Ehrenfeld ([45], p. 49) defines sustainability as "the possibility that human and other life will flourish on the planet forever". Sustainability is also grounded in wider concepts, such as environmental sustainability and sustainable development. In other cases, sustainable innovation refers to eco-innovation or clean(er) technologies or innovations that have superior ecological performance.

The OECD has distinguished between innovation and eco-innovation by setting out two additional characteristics for eco-innovation: that the innovation results in a reduction of environmental impact, whether this impact is intended or not; and secondly, that the scope of the eco-innovation may go beyond the conventional organisational boundaries of the innovating organisation and involve broader social arrangements that trigger changes in existing socio-cultural norms and institutional structures [46].

Bringing the two terms, sustainability and innovation, together, Charter and Clark ([47], p. 9) define sustainable innovation as "a process where sustainability considerations (environmental, social, financial) are integrated into company systems from idea generation through to research and development (R&D) and commercialisation". This applies to products, services and technologies, as well as new business and organisational models; as in the OECD definition, these innovations will often be characterised by systemness and radicalness and go beyond regular product and process innovations [47,48]. Carrillo-Hermosilla *et al.* [49] reviewed innovation definitions that focused on environmental innovation and eco-innovation and developed a consensus definition of sustainable innovation as "innovation that improves sustainability performance" (p. 1075), where this performance includes ecological, economic and social criteria. Yet, they left undefined the degree of performance required in each of these three categories or whether performance in each is required and, if not, which of the three criteria should be prioritised.

We have some knowledge about the factors that induce sustainable innovations, such as regulation and the stability of regulation, firm characteristics [50], as well as the impact of broader market-based instruments, such as carbon pricing, to stimulate market demand [51] and about the connection between innovation systems and how the adoption of sustainable innovations occurs [52].

There are several typologies of sustainable innovation that have been developed over a number of years. The work of Brezet [53] and the Rathenau Institute [54] each identifies multiple layers of innovative activity. Brezet [53] details four levels of innovation in the evolution of sustainable products and services, including product improvement, product redesign, functional innovation and system innovation. The work shows the cycle of increasing radicalness of innovations in the successive waves of innovation and also the increasing "openness" or need for external participation in the innovation process through the evolution of stages. The Rathenau Institute [54] emphasises a similar pattern of evolution, with innovations progressing from product improvements to functional changes, including new products and, then, system-level changes that require both technological and social and market structure innovations. Other authors also reflect on the multiple dimensions of sustainable innovation; Boons and colleagues [55,56] discuss three levels:

- The organisational level, including the traditional inputs and outputs of the innovation process and the pre-conditions that needs to exist in the firm to carry out innovative activities;
- The inter-organisational level, particularly the interactions along the supply chain and with market competitors; and
- The societal level, which draws on wider societal forces and how these forces shape what is considered valuable.

The demand side of sustainable innovation, which has been a neglected area of analysis until recently [57], highlights the mismatch in expectations between the demand and supply actors of sustainable innovation, as a cause for the slow diffusion of sustainable innovations. Success for innovation is generally defined as increased market share and profitable returns, and these largely accrue at the organisational or inter-organisational levels. Such success at the societal level is not accounted for and would largely depend on a complex array of variables and actors performing over a long period of time.

### *2.5. Contribution of Innovation Concepts*

Three areas of the innovation literature are relevant in developing more links between the business studies and industrial ecology fields, specifically in addressing the challenges of moving to (and increasing) product-centric recycling activities. Firstly, radical innovation; product-centric recycling will require technological, social and structural innovations for wider adoption. System-wide changes usually result from radical innovation. These innovations, in turn, have specific characteristics that distinguish them from other innovative activities, including larger resource requirements from firms' human and financial capitals. They involve greater risk/return profiles with, on the one hand, the opportunities of developing lasting and highly profitable competitive advantage, but this being accompanied by a great deal of uncertainty around how, when and where value will be created. Radical innovations also require the contribution of a wide range of external actors, such as research organisations, suppliers, customers, regulators and other specialist service providers.

The increasing need to coordinate external actors highlights a second contribution of the innovation literature: open innovation. Open innovation is an emerging model of innovation that acknowledges that most of the innovative activities undertaken by firms will occur outside of the firm. This literature highlights challenges that firms face in establishing and maintaining strategic networks across their supply and value chains. The literature also highlights how decisions about "openness" need to be embedded in a firm's BM for success.

The final area is also a rapidly emerging issue: sustainable innovation. Despite the growing prominence of the term, there are varied descriptions and definitions used. There is consensus that sustainable innovation has to meet additional criteria to other forms of innovation, namely higher levels of ecological performance (although increasingly, this could/should also extend to social performance, as well) and, again, the recognition that value creation will be the result of relationships across firms rather than activities within individual firms.

These additional demands on sustainable innovation make success difficult to define, as of yet, there are no widely agreed upon (by the business or the literature) pathways for co-creating economic and societal profits. It may be that the BMs available to current firms are not suited to sustainable

innovation challenges, because resolving economic, ecological and social goals within available BMs is not possible.

The literature provides a well-established basis for understanding sustainable innovations as an evolutionary process from small-scale redesign and process improvement, largely determined and driven by internal firm sources, to functional and system-level radical innovations that require many external interactions and knowledge sources. Questions the literature does not answer are whether these multiple levels of sustainable innovation are path dependent; does a firm have to be involved in incremental product design and process improvements to be a key player in later, more radical functional and system-level innovations? Further, what is the role of entrepreneurship in these innovations; is new firm formation a driver of creation and adoption of innovative practice? Are we more or less likely to see new firm formation based on the exploitation of sustainable innovation if a firm's stocks of external resources (which new firms by definition have less of) are as important, if not more important, than internal resources?

This is where insights from the BMs literature can offer further insights into how firms at a strategic management level operationalize sustainable innovations in their firms, particularly how this is evident in the changes they make to their BMs.

### **3. BMs and BM Innovation for Sustainability**

#### *3.1. Defining BMs*

There are multiple definitions of the term “business model” [58] with the word “business” meaning the way a company does business or creates value, whilst the term “model” expresses a conceptualization of something; in this case, of how a company does business. An example of a BM is Dell's supply chain, which allows for a negative cash conversion cycle, or eBay's way of earning a commission for putting buyers and sellers together [59].

Recently BMs have emerged as a new unit of analysis, yet there is lack of consensus on what BMs contain. Alberts [60] has conducted extensive research of all previous meta-BMs, including identifying the elements that make up a BM. Table 1 summarises the key popular BMs in the management literature. From the variety of definitions presented in Table 1, a BM can range from an activity system [61–64] that structures the way firms identify and exploit business opportunities, to a tool that provides a resource-based view of the firm's ability to change and introduce innovation [65]. Recent research by Plé, Lecocq and Angot [66] combines the Resources and Competences, Organization, Value Proposition framework of Demil and Lecocq [58] and the customer participation literature to develop the theoretical framework “Customer-Integrated Business Model”. This BM is centred on customer participation, where the customer is considered as a resource and where this resource has significant consequences on the value proposition and organization, as well as the interrelations between the three. This builds on the notion that value creation occurs through firms acting together and in partnership with other organisations (such as public research organisations) [67]. Therefore, the structure and characteristics of these collaborations are central to the BM.

**Table 1.** Summary of meta-business models (BMs). Reproduced with permission from [60]. Copyright 2011 Alberts.

| List of meta-BMs used (#) | Authors   | Based on BM   | Definition as per each BM  |
|---------------------------|---|---|--|
| 1                         | Zott and Amit (2001, 2007, 2008 and 2010) [61–64] | Activity System                                     | The content, structure and governance of transactions designed so as to create value through the exploitation of business opportunities.   |
| 2                         | Gordijn and Osterwalder (2005) [68]               | E3-value  | Constellation of enterprises and final customers that jointly create, distribute and consume things of economic value.   |
| 3                         | Demil and Lecocq (2010) [65]                      | Resource, Competency, Organisation and Value (RCOV) | The BM is considered as a concept or tool to address change and focuses on innovation, either in the organization, or in the BM itself.  |
| 4                         | Hedman and Kalling (2003) [69]                    | BM Concept  | No “proper” definition is given; instead, three other articles are referenced, producing an initial list of concepts.  |
| 5                         | Morris and Schindehutte (2005) [70]               | Entrepreneur’s BM                                   | A BM is a concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture and economics are addressed to create sustainable competitive advantage in defined markets.     |
| 6                         | Yunus <i>et al.</i> (2010) [71]                   | Social BM   | Close to “social entrepreneurship” BM; as defined by Mair and Marti [72] as “a process involving the innovative use and combination of resources to pursue opportunities to catalyse social change and/or address social needs”. |
| 7                         | Kim and Mauborgne (2000) [73]                     | BM Guide  | A BM is not defined and simply used as management tool.  |
| 8                         | Wirtz <i>et al.</i> (2010) [74]                   | 4C Internet Typology                                | A BM reflects the operational and output system of a company and, as such, captures the way the firm functions and creates value.  |
| 9                         | Lumpkin and Dess (2004) [59]                      | Internet BM   | A BM is a method and a set of assumptions that explains how a business creates value and earns profits in a competitive environment.   |
| 10                        | Osterwalder and Pigneur (2005 and 2010) [75,76]   | BM Ontology   | A BM is a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific firm.   |

Osterwalder and Pigneur [75,76] see BMs as a conceptual tool that highlights how a business defines its product and service offerings to the market and its competitive strategy for doing so. They treat BMs as conceptual tools in the sense that they can be used for analysis, comparison, performance assessment and communications.

Other BM definitions also exist for specific firm situations, such as entrepreneurship/start-up modes, where the focus of the business is on distinguishing the competitive advantage and markets of the new ventures [70], or an Internet-based BM [74]. BMs for firms that combine the economic exploitation of opportunities with a wider definition of “value creation” beyond economic value by also including social and environmental goals are emerging. The social enterprise model of Yunus *et al.* [71] is probably the most well known. Broadening the social BM concept to include environmental value (both separately and in combination with social value), this category of model also aligns with the emerging green BMs. These are discussed further in the next section.

A useful definition of a BM depends on the use of the model: is it to structure internal and external activities; communicate the benefits of product and service, and target markets; execute on strategic goals, including social and environmental goals; analyse and compare business performance, both before and after strategy implementation, and across firms; or a combination of some or all of the above? For the purposes of understanding how sustainable and radical innovations enable the wider adoption of product-centric recycling activities, a combination of the BM definition as an activity system as outlined by Zott and Amit [61–64] in combination with aspects of opportunity creation and exploitation and the need to communicate distinctive competitive advantage, it is suggested that the entrepreneurial, Internet and social BMs [60–62] are most relevant.

### 3.2. Sustainable BMs Innovation

The BM literature provides great diversity in understanding what a BM is, what it includes and how it does (or does not) organize the internal and external resources of the firm to identify and exploit business opportunities. The previous section established some characteristics to sustainable innovation, including it being an evolutionary process from incremental and internal redesign and process improvements, to externally focused functional and systemic changes; also, that sustainable innovation requires additional ecological and system-level impacts in addition to the characteristics of all innovations and in a way that can be conceptualised in a market relationship.

Sustainable innovation must operate successfully at multiple scales (economic, environmental and social) and solve the challenge of defining a pathway for the co-creation of both economic and societal outcomes. Sustainable BMs therefore must organise the firm’s resources (internal and external) to exploit opportunities presented by sustainable innovations.

Sustainable BM innovation is typically framed around the changing of the value proposition for the customer [74]. This can progress along two pathways. The first is where sustainable innovation creates a product or process that fits within an existing BM (e.g., switching from an energy-efficient light instead of one that is not). If we think of BMs operating at the organisational level, then little will have to change; if the BM operates at the inter-organisational level, then the firm will need to interact with the supply chain to be able to profitably deliver the service of lighting. The second is where the

BM innovation causes more fundamental change in the business, more than just changing products and services, but rather, changing the way business is done [62].

The literature provides a number of examples of what sustainable BMs may look like. Henriksen *et al.* [77] describes green BMs as “when a business changes part(s) of its BM and thereby captures economic value as well as reduces the ecological footprint in a life-cycle perspective” ([77], p. 10). The changes Henriksen *et al.* [77] detail only impact on part of the BMs, but in practice, green BMs that have wider impacts have also been identified. These include product-service systems, such as functional sales, energy service companies, chemical management services, integrated pest management, performance based pest management, sharing and renting BMs and design-build-finance-operate models [51]. The sharing and renting models represented by examples, such as AirBNB, perhaps represent the first moves toward more efficient resource use, which is causing changes at the system level.

Most of the sustainable innovations that are discussed to date, e.g., [78], have relied on the delivery of a superior (in terms of ecological performance) product that also has increased economic performance, such as energy efficiency products, or the delivery of current products in new service delivery models, for example, short-term car leasing arrangements instead of car ownership. In this case, ecological and social returns have been outweighed by economic returns, which have enabled the successful growth of the BM.

At the more conceptual level, Bocken *et al.* [79] have developed a categorisation of sustainable BM archetypes. After an extensive literature and practice review, eight archetypes are identified; maximizing material and energy efficiency; creating value from waste; substituting with renewables and natural processes; delivering functionality rather than ownership; adopting a stewardship role; encouraging sufficiency; repurposing for society/environment; and developing scale-up solutions [79]. For each of these archetypes, a value proposition and method of value creation, delivery and capture are detailed, and specific BMs sit under each of these archetypes.

These categories display similar evolutionary progression as that detailed in the sustainable innovation literature, *i.e.*, a progression from less complex, individual firm-focused BMs, to more complex BMs that require the participation of multiple firms and organizations for value creation, delivery and capture. The archetypes are not mutually exclusive in that a specific business or BM could include aspects of a number of archetypes. In the specific case of product-centric recycling, business opportunities could fall into a number of archetypes; obviously creating value from waste archetype, but also maximize material and energy efficiency, deliver functionality rather than ownership, adopting a stewardship role, repurposing for society/environment and developing scale-up solutions.

The archetypes are also focused on BMs that are operating or attempting to operate in the current socio-economic conditions. Therefore, evolution in the archetypes would be expected as both new supply and demand conditions influence innovative activity in this area.

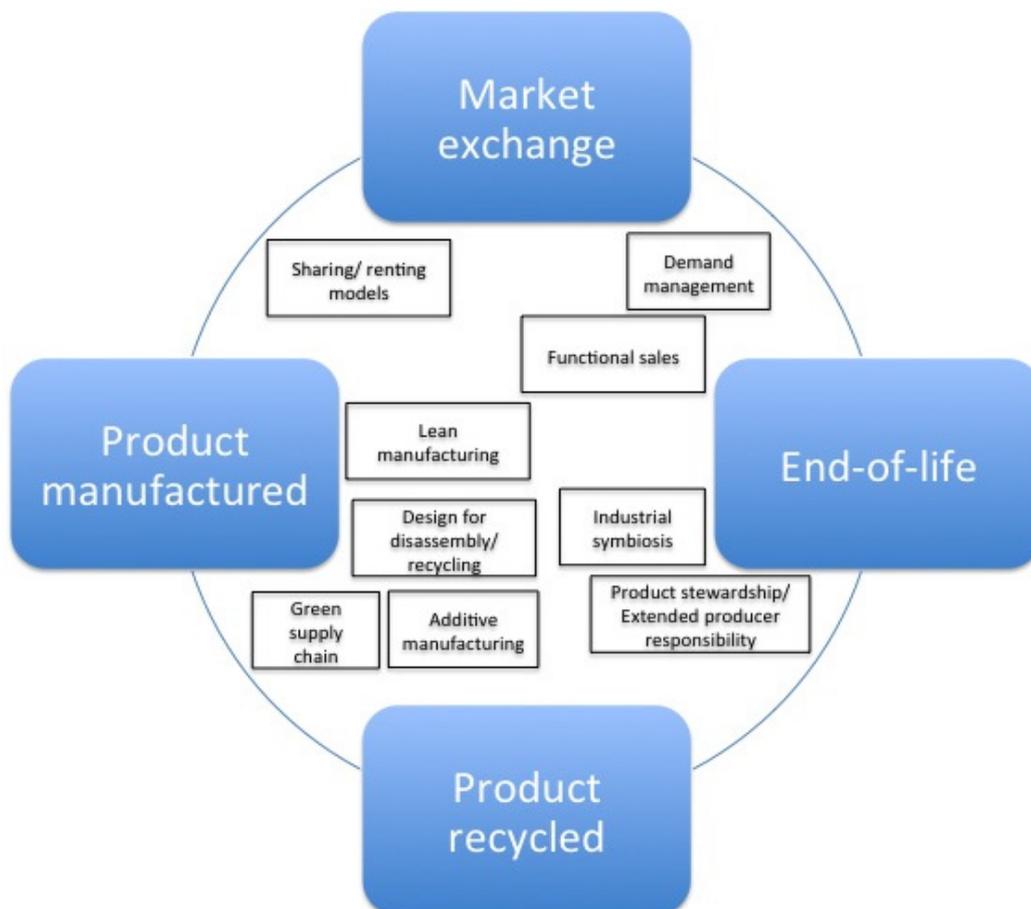
Boons *et al.* [55] have provided a more conceptual view of a sustainable BM building from the sustainability literature, and they take four key concepts of BMs and describe sustainability across the three levels mentioned earlier (organisational, inter-organisational and societal level) for each of the concepts:

- A value proposition that provides measurable ecological and/or social value in concert with economic value;

- A supply chain with suppliers taking responsibility towards their own, as well as stakeholders' socio-ecological burdens and not deflecting this to others in the supply chain;
- A customer interface that motivates customers to take responsibility for their own consumption. The firm does not shift socio-ecological burden to customers, and customer relationships are set up with the recognition of the respective sustainability challenges of differently developed markets, as well as company-specific challenges resulting from its individual supply chain configuration; and
- A financial model that reflects an appropriate distribution of economic costs and benefits among actors involved in the BM and accounts for the company's ecological and social impacts ([55], p. 9).

This work is valuable in setting the overall principles for what a sustainable business environment would entail, but it does not offer guidance on how individual firms can operate in this business environment. Referring back to the product-centric recycling approach, Figure 1 shows the stages of production, consumption and recycling if applying this approach. Mapped on to the cycle are some of the evident sustainable BMs. This again shows the importance of linkages between firms in operationalizing this approach, as it is unrealistic that a single firm or even several firms will be able to provide the infrastructure to enable this approach for a single product or product class. The challenge will be for firms to create and maintain links across the cycle to enable knowledge exchange, facilitating radical and open sustainable innovation and providing learning on sustainable BM innovation across the network. This is where the continued linkages are between the industrial ecology and innovation fields.

**Figure 1.** Varied sustainable BMs possible within the product-centric recycling approach.



#### 4. Conclusions and Gaps for Further Research

The declining availability of natural resources and the environmental impacts of the continued extraction of primary resources for production activities have forced greater focus on waste streams and recycling activities. Recycling activities have become increasingly complex and integrated in recent years, corresponding with the greater sophistication of industrial production activities and consumer goods. This increasing sophistication of recycling processes requires corresponding efforts in generating collaboration and network linkages across disparate components of industrial activities; requiring fundamental innovation within and realignment of supply and value chains.

Industrial ecology is a field of practice and theory that has long been linked to sustainability, with it being referred to as the “science of sustainability” [4]. Despite the development of much theory and specific tools and methodologies (e.g., Life Cycle Assessment and Material Flow Analysis) making the link between the natural and industrial systems, the further link to economic systems is not well articulated, and the interaction with business studies and industrial investment decision-making remains under-developed [5–7].

Through the constructive approach taken, this paper explores how two areas of literature can support the development of the industrial ecology field into strategic business practice. The first area is the innovation literature, particularly the emerging work on open innovation and sustainable innovation as a model to understand radical innovation processes and the creation and maintenance of networked systems of firms.

Product-centric recycling will require technological, social and structural innovations for wider adoption; such system-wide changes usually result from radical innovation. Radical innovations have specific characteristics that distinguish them from other innovative activities, including requiring larger human and financial capital resources from innovating firms. They also involve greater risk/return profiles with, on the one hand, the opportunities of developing lasting and highly profitable competitive advantages available to innovating firms, but on the other hand, they have a great deal of uncertainty around how, when and where value will be created by these innovations and accessed by the innovating firm. Radical innovations also require the contribution of a wide range of external actors, such as research organisations, suppliers, customers, regulators and other specialist service providers. This requires innovating firms to have sophisticated knowledge-sourcing networks to be able to develop and commercialise any innovation.

The increasing need to coordinate external actors highlights the potential major contribution of the innovation literature, in the form of open innovation. Open innovation is an emerging model of innovation that acknowledges that most of the innovative activities undertaken by firms will occur outside of the firm. This literature also highlights how decisions about “openness” need to be embedded in a firm’s BM for innovation success, although work and theory development is continuing within the literature about how this embedding process is best carried out.

Both radical and open innovation processes are inherent in sustainable innovations. Despite the growing prominence of the term, there are varied descriptions and definitions used, but there is agreement that sustainable innovation has to meet additional criteria to other forms of innovation, namely higher levels of ecological performance (although increasingly, this could also extend to

social performance, as well) and, again, the recognition that value creation will be the result of relationships across firms rather than activities within individual firms.

These additional demands on sustainable innovation make success difficult to define, as of yet there are no widely agreed upon (by the firms or the literature) pathways for co-creating economic and societal profits. This is a major and remaining challenge for sustainable innovation and will require further investigation at the theoretical and empirical level. Whilst this paper articulates the use of the constructive approach, this has its limitations, as one of the conditions of a successful constructive approach is its practical implementation of the construct developed [80–82]. This paper indeed lacks that, and as such, a constructive study in the future is highly recommended.

The lack of these pathways means that sustainable BM innovation is also being stymied. The emerging typologies of sustainable BMs at both the conceptual and empirical levels offer some hints about how this may happen, but to date, they do not have, at their heart, strategies for developing radical and open innovation processes and network linkages across wider areas than just the traditional supply chain.

It may be that the BMs available to current firms are not suited to the sustainable innovation challenges, because resolving economic, ecological and social goals within available BMs are not possible. As the value proposition of these innovations cannot be fully presented to the market in a form that allows for the capture of the all of the value that the innovation introduces, new BMs will need to be developed, tested, adapted and promulgated. Further exploration of the limited ability of sustainable innovations to conceptualise ecological and social value may also warrant public policy attention. All of these issues will need extensive investigation at the empirical level before we can be in a better position to advise business and government actors on appropriate courses of action. Perhaps, through a constructive study, a closer methodological look at the technical sciences, medical field, clinical studies and other problem-oriented fields needs to be undertaken to fully understand the potential of the constructive approach in management.

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## Conflicts of Interest

The authors Samantha Sharpe and Renu Agarwal declare no conflict of interest.

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