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Supply market uncertainty: Exploring consequences and responses within sustainability transitions

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ABSTRACT

Often it is commercial, not technological, factors which hinder the adoption of potentially valuable innovations. In energy policy, much attention is given to analysing and incentivising consumer demand for renewable energy, but new technologies may also need new supply markets, to provide products and services to build, operate and maintain the innovative technology. This paper addresses the impact of supply constraints on the long-term viability of sustainability related innovations, using the case of bioenergy from organic waste. Uncertainties in the pricing and availability of feedstock (i.e. waste) may generate market deadlock and deter potential investors. We draw on prior research to conceptualise the problem, and identify what steps might be taken to address it. We propose a research agenda aimed at purchasing and supply scholars and centred on the need to understand better the interplay between market evolution and supply uncertainty and 'market shaping' – how stakeholders can legitimately influence supply market evolution – to support the adoption of sustainability related innovation.

1. Introduction

Firms and policy makers make great efforts to encourage demand for innovations which yield environmental and social benefits. Purchasing and supply management (PSM) experts support these endeavours in various ways including sustainable procurement (Meehan and Bryde, 2011), green/sustainable supply chain management (Seuring and Müller, 2008), and using public procurement to promote innovation (Rolfstam, 2012). These initiatives all have a vital role to play in helping organisations meet their sustainability related objectives. This article argues that there is however an important gap in PSM research – a gap that is broadly relevant to many situations involving innovation but is particularly important to sustainability. We show how supply-side market failure can constrain or even block the take-up of sustainability related innovations, and that this important topic has, to date, been largely neglected in scholarly work in PSM. Based on an extensive review of the literature and informed by practical examples – in particular on the example of 'bioenergy from organic residues' (BfOR), one aspect of the renewable energy 'sustainability transition' (Markard et al., 2012) – we propose a research agenda for supply market research. The issues discussed are acute in BfOR but not exclusive to this field, so the agenda is of wider relevance.

In the BfOR sector, uncertainty about price and availability of 'residual biomass feedstock' – organic waste such as agricultural by-products or household rubbish – is often a critical factor in deterring investment in individual BfOR projects (Scott et al., 2013). At the collective level, a vicious cycle may emerge and block or constrain innovation adoption: uncertainties in feedstock supply dampen, or prevent, the development of demand, which in turn means that waste producers do not regard bioenergy plants as a market of potential buyers, and do not enter that market. Over time and across the system of potential vendors and buyers, buy-side and supply-side uncertainties are mutually reinforcing, potentially leading to a form of market failure, which may block BfOR adoption ('market deadlock'), or slow adoption ('market bottleneck'). These operate as a barrier to the transformative change that is needed for the transition to renewable energy. Though supply market deadlock/bottleneck and buying firms' responses are clearly supply management related, an initial review of the literature demonstrated a lack of relevant PSM research. The aim of this article is therefore to address two questions in the context of sustainable transitions:

- how does supply uncertainty constrain innovation adoption?
- what measures can be taken to address supply uncertainty when it constrains innovation adoption?

The article is organised as follows. Section 2 describes the process of the extensive, exploratory literature review, and how

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the BfOR example and other relevant examples were used to inform the analysis, working back and forth between practical cases and conceptual knowledge. Section 3 describes the case of 'distributed bioenergy from organic residues' (BfOR), which provides an example to illustrate and inform the analysis of literature related to the two research questions; it is not formal, primary research. Section 4 presents key findings related to the first question, which serves to elucidate the nature of the problem. Section 5 is focused on what measures might be taken to address it. We conclude by presenting a proposed research agenda and discussing its implications in terms of research process (theory and method), with implications for policy and practice.

The focal topic of this article lies at the intersection of research in three fields, PSM, innovation and sustainability. Most research at the intersection of PSM and sustainability focuses on environmentally and ethically sound supply chain practices (Pagell and Shevchenko, 2014), and most research at the intersection of PSM and innovation focuses on purchasing and supply issues related to bringing new products to market. By contrast, here we link established PSM themes to the field of sustainability related transitions (Markard et al., 2012; Frantzeskaki et al., 2011).

This article makes three contributions. First, it elaborates the concept of market deadlock/bottleneck in relation to supply uncertainty, linking public policy and innovation studies to the field of purchasing and supply management (Section 4). The second contribution is to elaborate firm level, market taking (Spulber, 1996) responses to market bottlenecks, that is strategies firms adopt to mitigate supply risk and uncertainty which presume the firm cannot influence the market (Section 5.1). The third contribution is to elaborate market shaping strategies and activities to address bottlenecks and deadlocks (Section 5.2). The second contribution can be seen as incremental to the PSM field, extending supply risk and uncertainty research to a new field. The first and third are more novel; 'market' as a level and unit of analysis is relatively neglected, even within the field of marketing (Storbacka and Nenonen, 2011a), and is often not defined explicitly (Geroski, 1998; Biggart and Delbridge, 2004). Overall, we find that there is an urgent need for PSM research to better understand the impact of supply uncertainty on innovation adoption particularly in the context of sustainable transitions, and suggest ways in which supply management might help to address this barrier to transformational change.

2. Method

This article is rooted in a practical problem encountered by bioenergy experts. Through formal interviews and informal discussions with bioenergy experts, an initial statement of the problem was elaborated. Then a multi-phase, extensive and iterative search of business and management literature was conducted, as set out in Table 1. Stage 1 provided a small body of the literature which helped to elaborate the problem, but provided little on how it might be addressed. We therefore turned to the literature on innovation and supply (stage 2), and then pursued key themes emerging from stage 2.

The diversity of focal topics, perspectives, methods and disciplines within the set of articles reviewed here limits the value of the typical 'gap-spotting' approach to reviewing the literature and identifying areas for future research (e.g. Neely et al., 1995; Roehrich et al., 2014). Rather, our approach to reading the core texts has been guided by advice from Alvesson and Sandberg (2011) who advocate "problematization as a methodology for identifying and challenging assumptions" and identifying interesting avenues for new research. Making sense of the literature was an exploratory and iterative process, involving problem statements and thought trials (e.g. Weick, 1989; Cornelissen, 2006). We related insights from prior research to the BfOR situation and other cases (see Table 2), considering for example the potential consequences of widespread adoption of various sourcing strategies (see Section 5.1). Rigour was achieved by pursuing themes persistently and consistently with the goal of achieving saturation, systematically checking for further work which might either extend or complement the insights generated or provide disconfirmatory evidence, or till new articles were found to be out of scope/relevance. We use empirical material from BfOR and reported cases with knowledge from prior research in a dialogic approach (Alvesson and Kärreman, 2007). BfOR is not a primary case study, but a rich example presented using the academic literature and building on extensive, direct experience in the sector by one of the authors (Scott). Next, we describe the BfOR sector and key barriers and drivers of change which relate to supply.

3. Bioenergy from organic residues

BfOR technologies have the potential to improve the overall environmental sustainability of economies and societies by simultaneously generating energy with lower environmental impacts compared to fossil fuel sourced energy, and reducing the negative environmental impact of waste management activities (Kothari et al., 2010; Iakovou et al., 2010). The waste hierarchy concept for resource management indicates that reuse and recycling of material are better than converting materials to energy (recovery), and that recovery is preferable to disposal (Grosso et al., 2010; Schmidt et al., 2007). Therefore the BfOR industry focuses on residual materials that cannot be economically recycled. BfOR is distinct from energy from waste (EfW) as EfW projects and technologies are designed to handle mixed waste materials usually with high plastic contents, mainly through incineration. The industries do however overlap with respect to actors and technologies.

Examples of biogenic wastes are food waste from the food retail supply chain, straw and husks from agricultural processes, sewage sludge and the residual fraction remaining after municipal waste is processed through a recycling plant. Different types of feedstock are more or less suitable for different conversion technologies. Each feedstock has different technical and legislative challenges for project developers to overcome. Energy in this context means either heat or power, or both produced in a combined heat and power (CHP) plant (Gold and Seuring, 2011; Kaltschmitt et al., 2009).

Waste producers include municipalities and actors within agricultural, food, drink and forestry supply chains. Waste merchants or intermediaries including recycling companies, haulage companies, warehousing and general logistics firms. Aggregation and sorting activities are also common in some parts of the organics recycling industry, especially waste wood. BfOR plant operators include large scale utilities and multi-national engineering firms with consortium finance backing. At the small scale, BfOR can be community run organic waste management projects, biomass boilers or small scale CHP schemes. Usually projects will have a developer from the beginning who takes most of the at-risk development work. Once planning permission is granted the project is effectively live and is often then sold to a larger development firm with a greater liquidity to complete the actual build and commissioning. Sometimes projects will also change hands post commissioning to a more risk averse operator, typically a utility.[1]

[1] This summary is based on extensive interaction with various BfOR stakeholders, and literature such as WGBU (2008), Kaltschmitt et al. (2009), Gold and Seuring (2011) and Gold (2011).

Table 1
Key stages and outputs of the iterative, exploratory literature review.

Focus/stage	Process	Key output/findings
1 Supply market evolution	Exploratory, using Web of Science and Proquest, seeking empirical and conceptual research (not modelling)	Framing the practical problem in terms of risk and uncertainty, and that innovation in the problem context related both to emerging technologies and emerging markets.
2 Innovation and supply, and risk/uncertainty and supply	Proquest database, 2 search strings: 1) *Abstract (innovat*) AND Title (supply OR purchasing OR procurement)* yielded 650 hits; 204 abstracts were reviewed; 84 articles were identified for closer reading. 2) Abstract (risk OR uncertainty) AND Title (supply OR purchasing OR procurement OR contract) and Anywhere (emerg*) yielded 534 hits; all abstracts were reviewed, 69 articles were identified for closer reading. These articles were analysed by two of us (Knight and Pfeiffer) and coded to inductively derive themes to provide conceptual and practical insights on the focal problem.	Themes identified: • market failure and government policy, including public procurement of innovation; • supply chain actors' motivations and connectivity; • co-evolution of supply and demand; • nature and novelty of products and markets; • nature of uncertainty in supply markets and supply chains: declining and volatile supply; • social construction of markets.
3a Themes from previous stage plus (e.g. market failure) 3b Alternative terms (e.g. 'nascent' instead of 'emerging') 3c Tracing the work of key authors	Further, numerous exploratory searches, following themes and leads in core literature from previous stages	Deepening understanding of core themes, clarifying boundaries and intersections between this work and established topics within PSM research
4 Sustainability transitions and supply	Using Proquest, search string Anywhere ("sustainability transitions" And (purchasing or supply)).	Confirmation of the policy and demand side focus in the ST literature.
5 'Market innovation'	Review special section in Industrial Marketing Management (Jan 2015)	Insights on upstream (not consumer related) supply market shaping processes and practices

Table 2
Eco-innovative solutions constrained by supply uncertainty.

Sector	Examples
Medical technology	Phillips et al. (2011) show the impact of regulation and reimbursement regimes on the emergence of tissue engineering products
Housing	Lovell (2005) provides a rich description of the supply side and the demand side of the ecohousing market, showing how demand has not been met by supply
Offshore wind energy	Wieczorek et al. (2013, 304) found the availability of vessels was adequate for current offshore wind energy production in Europe, but was seen as a potential future constraint if the market did not adapt to support operation in deeper waters.
Electric vehicle energy services	Weiller and Neely (2014) describe how the three systems associated with using electric vehicles for energy services – "vehicle, charger and grid – are managed by different agent from different industries (automotive, electricity supply and charging equipment) whose relationships are largely uncooperative" (p199), and the negative impact this has on adoption
Electric vehicle	Dijk and Yarime (2010) provide a rich description of the co-evolution of supply and demand in the emergence of electric engines in the automotive market since 1990. Their analysis includes micro (agent) and macro (aggregate) levels, and maps feedback mechanisms between levels, and micro to micro
Mineral resource	Hensel (2011) shows how the limited supply of rare earth materials is affecting renewable energy technologies such as wind turbines, electric vehicles and solar panels

Whilst 'advanced biomass conversion technologies' such as pyrolysis and gasification of residual wastes (Arena, 2012; Asadullah, 2014) are more technologically complex; advantages include improved conversion efficiency, higher value by-products and the production of stable energy vectors. Products include synthesis gas (syngas) from gasification, biogas (methane rich gas) from anaerobic digestion and various bio-oil products from pyrolysis and refining that can be moved or stored. These intermediate products can then be upgraded to higher value base chemicals making biomass waste feedstock important for the continuing decarbonisation of modern societies. However, advanced BfOR technologies are more sensitive to changes in composition and quality of feedstock than incineration technologies, and carry the inherent technology risk associated with using emerging processes (Adams et al., 2011; Wright et al., 2014). These risks are counterbalanced by the enhanced value of products, greater overall efficiency and the bonus of government incentives.

Sending organic material to landfill or incineration is discouraged via taxes on landfill tipping (Scharff, 2014) whilst the use of sustainable biomass for energy generation is encouraged via production incentives (Diaz-Rainey and Ashton, 2008; Verbruggen and Lauber, 2012; Wordsworth and Grubb, 2003), which are used to compensate for the extra capital cost and technology risk experienced by advanced BfOR technologies (Thornley and Cooper, 2008). Despite the favourable incentive regimes, a survey of new waste treatment infrastructure in the UK by Nixon et al. (2013) found that the lower capital cost, well established, large scale incineration technologies remain popular with waste management companies and municipal councils for waste disposal.

The stability of the business case over the financing period highly influences the successful development of projects and technology deployments (Adams et al., 2011; Scott et al., 2013). The price and availability of feedstock are critical elements of this business case. Several factors, generate uncertainty for project finance including changing tax, incentive and waste regulations. On the supply side, rising demand from buyers, increasing efforts to reduce waste sent to landfill and to generate revenue from waste would increase availability. However, waste reduction

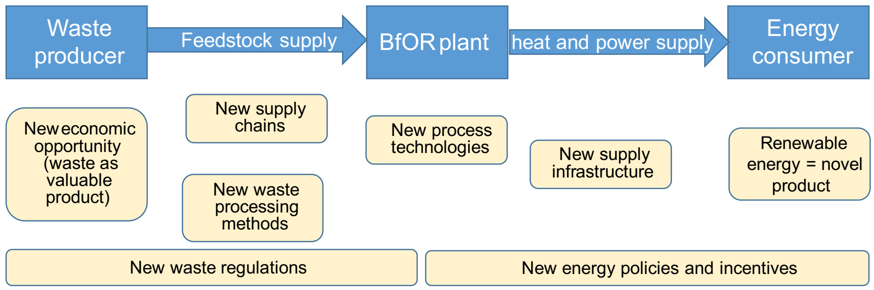

Fig. 1. Illustrating the many facets of newness in the BfOR supply chain.

strategies combined with increasing reuse and recycling would reduce availability of waste for BFOR feedstock. Competition from other buyers, such as incineration projects (offering security of long-term contracts) and, in future, the biorefining industry (possibly offering higher prices given higher value added outputs), would also reduce availability of feedstock for BfOR plants.

In summary, there is much uncertainty about the supply of waste and feedstock, in terms of its value and the volume of the market. The balance and rate of change of supply and demand are therefore difficult to estimate, especially as biorefinery concepts begin to enter the market. In the medium term the various factors discussed above mean supply volume could reduce and cause prices to rise. In this setting, shorter-term contracts are more attractive for sellers, rather than the long-term contracts sought by developers. Hence, financiers are deterred by this risk and novel waste-to-energy plants might never be built (Deloitte, 2012; Gold and Seuring, 2011). The issues raised here are considered from a conceptual perspective in the next section, and then in Section 5 from a practical perspective.

4. Framing the problem

Here we present the main findings from the literature review that address the first research question: 'In the context of sustainable transitions, how does supply uncertainty constrain innovation adoption?' Based on the themes identified inductively from the second stage of the literature review (see Table 1), we address the various elements of the first research question to more clearly define the focal problem. We begin by reviewing innovation in the context of sustainability, and vice versa. This indicates the importance of PSM to the field, and yet also the limited relevance of prior research. Second, we consider the motivations for innovation adoption and consequent supply chain priorities, noting important variations depending on whether energy production is core business, and whether or not motivations are solely economic. Third, we examine the drivers of supply uncertainty. The final section reviews the impact of these uncertainties on the evolution of the market, covering co-evolution of markets and market failure, and so linking the discussion back to innovation adoption.

4.1. Characterising innovation and sustainability

Consideration of what is new in the BfOR case leads to a complex picture, summarised in Fig. 1, of emerging supply markets of novel commodities (various forms of processed waste) for use in emerging technologies (renewable energy production technologies such as pyrolisers, anaerobic digesters and gasifiers, and their use in combination) to produce a relatively novel product (renewable energy) which often requires new infrastructure and governance arrangements (for energy distribution). All these changes take place in a developing policy context with the dual, sometimes divergent foci of waste regulation and energy policy. Relating this to Sandberg and Aarikka-Stenroos' (2014) categorisation of innovation,[2] we observe that the transition to renewable energy in general, and BfOR specifically, are disruptive innovations, within which we find all forms of radical innovation as well as incremental innovation. Our review, in particular step 2 (see Table 1), shows however that supply scholars tend to investigate cases where novelty relates either to the supply base (established products acquired from new suppliers), or to the focal product/process (new products are required). There is little research where both supply and demand are subject to innovation driven uncertainty, and the context is also innovative (but see e.g. Harris, 2000; Li and Barnes, 2008).

The field of renewable energy is a context in transition. It is extensively studied by innovation scholars adopting a variety of perspectives rooted in evolutionary economics and sociology of technology (Karltorp, 2014, 9–11), and which have recently come under the umbrella term 'sustainable transitions', including for example multilevel perspective (MLP) (Smith et al., 2010) and technological innovation system (TIS) (Jacobsson and Bergek, 2004). The sustainable transitions (ST) literature offers approaches to describe change and innovation across levels, in broad sectors and over the long term. Whilst MLP has been critiqued for lack of attention to agency (e.g. Garud and Gehman, 2012), TIS blends structural components and processes (Jacobsson and Karltorp, 2013). The ST literature also provides some examples of supply uncertainty acting as a barrier to innovation adoption in energy transitions (see Table 2). But, it seems to offer only very few, and only implied, links with supply market or supplier analysis and management. For example, articles on offshore wind energy (Wieczorek et al., 2013; Jacobsson and Karltorp, 2013) show that supply issues are important (infrastructure, shipping and copper cables), but also that: the framing underplays supply, though there is considerable attention to the demand side of markets; supply matters are subsumed in processes which do not draw attention to developing commercial relationships and supply market capacity and capability along the supply chain. For example, in Karltorp's (2014) rich descriptions of windpower and biorefining, supply issues are raised but in terms of two (of seven) key processes, 'resource mobilization' and 'entrepreneurial experimentation'.

We conclude that the perspectives on innovation and sustainability in transition studies have much to offer, to complement PSM research on environmentally and ethically sound supply

[2] Sandberg and Aarikka-Stenroos' (2014, 1295–1296) use 'dimensions and degrees of newness' to classify articles on radical innovation: new to firm, new to market, new to the firm and to the market, and disruptive innovations, with the latter perceived as concerning "new business models that disrupt existing market and value networks and transform the business landscape".

chain behaviours and on bringing new products to market. Categorising innovation in terms of process or product innovation, or incremental or radical innovation, is valuable when zooming in on local projects, but less so at the broader system level. On the other hand, the more descriptive, structural and policy orientation of the ST body of work, combined with the relative lack of attention to supply-side aspects is limiting. Very few organisation and management studies scholars have addressed this space (but see Möller, 2010; Garud and Gehman, 2012).

4.2. Motivation for innovation and supply chain priorities

Here we consider organisations' motivations for innovation adoption (which, in the case of BfOR, is CHP generation from waste using advance biomass conversion technologies), and their consequences for supply chain priorities. BfOR projects are typically small scale and distributed. Some are established by enterprises for which energy production is their core business. 'Green energy' is a differentiated product attracting at best a modest price premium. Even social entrepreneurs, motivated by positive externalities (Santos, 2012), would have a strong cost focus. Feedstock acquisition is central to such firms' business strategy.

A more complex picture emerges however where energy production is not the central purpose of the organisation, as in the case of an industrial bakery's closed loop supply chain described by Jensen et al. (2013). They map the various combinations of environmental, marketing and economic factors motivating the supply chain actors' participation. They emphasise the scope for value creation in green supply chain innovations, rather than mere cost avoidance. Establishing such 'closed loop' supply chains (Wells and Seitz, 2005) may be part of efforts to 'green' supply chains. Research on industrial symbiosis (Bain et al., 2010) shows an alternative view, with firms motivated to participate by resource scarcity (Bell et al., 2012) and price volatility (Schoenherr et al., 2012, 4564–65). Unreliable electricity supply may also motivate self-sufficiency in power generation (Gulyani, 1999, 1764).

Further articles described cases where social objectives were apparent, promoting community level benefits and a local perspective. This is particularly evident in publications relating to the agri-food sector, where complex combinations of social, political, or economic objectives motivate local communities to be self-sufficient (Chiffoleau, 2009) or to extend their influence beyond local boundaries (Oglethorpe and Heron, 2013). Substantive rationality – oriented towards values – can motivate exchange: "substantively rational action is rational in the sense that action is predictable and not capricious, but it need not follow the procedural rigour of instrumental rationality, and actors feel morally or emotionally bound to pursue the substantive goal (e.g. fight poverty), even if they are not successful in achieving the end. The probability of success is not critical to substantive rationality, whereas it is always part of the calculus of instrumental rationality" (Biggart and Delbridge, 2004, 34).

This wide variety of motivations for innovation is likely to lead to variation in supply chain performance expectations. Melnyk et al. (2010) present six types of supply chain outcomes (cost, responsiveness, security, sustainability, resilience, innovation) that can be prioritised, often in combination, and sometimes in tension. The literature discussed above points to complex blends of BfOR operator priorities (cost, environmental, social, marketing etc.) leading to an equally complex set of requirements at the supply chain interface with feedstock suppliers, with security of supply and low cost being central, but also an interest in community, ecological and reputational benefits. Next, we explore security of supply further, by considering the sources of uncertainty in feedstock supply.

4.3. Sources of uncertainty in supply

Despite Knight's (1964, originally published 1921) conceptually clear distinction between uncertainty and risk, in this article we use the term uncertainty to also encompass risk, recognising that one firm's uncertainty may be seen as a risk by another firm. Furthermore, through market shaping (discussed below), a firm could 'convert' an uncertainty into a risk. We review the various sources of uncertainty, relating to the product's technical and commercial characteristics, logistical challenges, volatility of supply and demand, and supply chain and market configuration.

As indicated in Section 3, the feedstock product itself is a source of uncertainty. Often waste is more variable than advanced BfOR technologies' operating parameters, so processing is required. Relatively narrow parameters reduce sourcing options and switching opportunities. Much of the research reviewed focuses on higher tech products, with consequent high levels of buyer-supplier interdependence and dedicated supplier capacity (e.g. Phillips et al., 2011). In BfOR, both waste and energy are more like commodities, though waste is relatively differentiated, and more so for some renewable energy technologies than others. There are additional logistical challenges arising from product instability (humidity levels, fire risks) and its relatively high bulk and low value.

In addition to operational aspects of demand and supply uncertainty (Paulraj and Chen, 2007), seasonality is a source of uncertainty. We found several articles give rich descriptions of supply chains which are designed to cope with volatility driven by uncertainties in demand (e.g. relating to fashion: Masson et al., 2007; relating to toys: Wong and Hvolby, 2007). Demand uncertainty in heat and power consumption is well understood, but for BfOR feedstock the uncertainty is also supply side driven, for example in the availability of agricultural waste products.

Oglethorpe and Heron (2013) and Hingley et al. (2010) researched local food supply chains, from the supplier perspective. Both report producers being disconnected from consumers, and market level problems for producers in establishing routes to market, whether through farmers' markets or via retailers or wholesalers. Hingley et al. (2010) found wholesalers acted as gatekeepers preferring the status quo and blocking local producers' market entry by favouring established import routes. Both papers highlight the role and many forms of intermediaries between producers and consumers, with Hingley et al. (2010) advocating "horizontal channel collaboration" to address the problems (p93). For many types of biomass (e.g. wood pellet; solid recovered fuels, wood chips and recycled or recovered wood and timber), commercial traders act as intermediaries in the supply chain providing distribution and processing services (Hämäläinen et al., 2011; Iakovou et al., 2010), effectively 'de-risking' the supply chain for BfOR plant operators. The place of such intermediaries within the supply chain is summarised in Fig. 2 below, which focuses on the economic and operational aspects of demand and supply in BfOR feedstock supply.

Given these sources of uncertainty in feedstock supply, driven both by demand and supply side factors, we turn next to considering market evolution and its potential impact on innovation adoption, drawing on the wider body of literature reviewed (see Section 3) and also other empirical cases.

4.4. Supply market evolution

Conceptually, the initial motivation of this study was to understand how supply markets evolve in new, sustainability related fields, but early literature searches yielded little directly relevant research (Table 1, stage1). The second stage of the literature search enabled a better understanding of the context of the focal

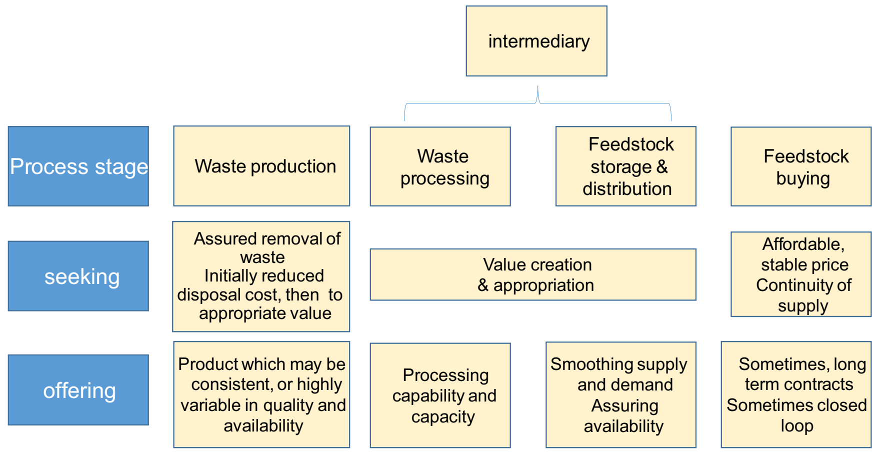

Fig. 2. Summarising operational and economic aspects of demand and supply in BfOR feedstock supply chain.

problem, and provided insights on two related aspects of market evolution: the co-evolution of supply and demand, and market failure. Both were explored further (Table 1, stage 3).

We begin by considering what markets need to evolve in the context of sustainability transitions. Contrasting examples in Table 2 and relating them to the case of BfOR leads to a number of observations. Often attention is on the final stage of the supply chain, to the end consumer (automotive, ecohousing, and renewable energy). Fewer articles relate to patterns of supply and demand upstream (tissue engineering products, and BfOR feedstock), or for ancillary products and services (service vessels, BfOR equipment, and infrastructure for heat and power distribution). In assessing co-evolution of supply and demand, consideration of the wider supply network is needed, evaluating vertical and horizontal relationships in the system. Generally more attention is given to the demand side than the supply side of cases (see also Baptista, 1999), and macro-level analyses predominate, especially in innovation studies (but see Dijk and Yarime, 2010).

Often markets do not co-evolve as might be expected. Where markets are seen as failing, governments may act “to improve upon market outcomes. They can do so either by substituting some other mechanism of coordination for the market or by changing the settings and rules for markets” (Hausman, 2008, 4). The concept of market failure and its use in public policy are both highly contentious (Bromley, 2007), but market failure is the central premise to using public procurement as an instrument for promoting the diffusion of innovation (Edler and Georghiou, 2007; Edquist and Zabala-Iturriagagoitia, 2012; Uyarra and Flanagan, 2010). And yet the upstream ‘reach’ of public procurement is limited. Whilst BfOR might be promoted through establishing CHP plants at government owned sites or public hospitals, for example, public procurement intervention regarding feedstock seems unlikely.

Building on MLP and TIS studies, Weber and Rohracher (2012) examined failures in transformative change. They present four established categories of system failures (infrastructural, institutional, interaction/network, and capabilities) and argue there are four further categories of failure (directionality, demand articulation, policy coordination, and reflexivity failure). ‘Demand articulation failure’ addresses issues of production and consumption, but this is conceived as only relating to end users as consumers. This focus on consumers and inattention to business-to-business (B2B) typifies much of the discussion of supply and demand within transition studies. A rare B2B example is found in Weiller and Neely's (2014, 199) work on electric vehicles' uses for energy services (energy storage, supply and load management). They propose that joint investment and a revenue sharing model are the critical first steps to overcoming strategic barriers. Weber and Rohracher (2012, 1042–1043) argue that collective coordination, as well as a shared vision is needed to achieve transformative change.

We conclude that, though not explicitly recognised elsewhere *as a supply matter*, the problem identified in the BfOR case – that there is a risk that BfOR technologies will not be adopted because feedstock supply uncertainties deter investors – is generalisable to other settings. According to Martin and Scott (2000), this is a form of market failure: “reliance on market processes alone will result in underinvestment”. But in this case the market failure is upstream of the ‘site of innovation’ rather than downstream. Where market failure is sufficiently acute to be regarded as blocking innovation, we term it ‘market deadlock’. Where market failure limits the rate or scope and scale of adoption, we term it ‘market bottleneck’. In both cases, the ‘system of exchange’ (Biggart and Delbridge, 2004) limits innovation. Furthermore, B2B market failures – whether deadlocks or bottlenecks – are not solely a policy matter, but may be addressed by market actors directly through collective, interorganizational coordination between or within buyer or supplier groups, or through actions by single, powerful market actors, as discussed in Section 5.

5. Addressing supply uncertainty

Here we present key findings relating to the second research question “what measures can be taken to address supply uncertainty when it constrains innovation adoption?” A critical factor here is how markets are perceived by actors. The dominant perspective within PSM has been on firms sourcing *within* market constraints to mitigate supply risk. In public procurement however, some PSM scholars have studied settings where supply markets are actively shaped by buyer-side market actors (e.g. Caldwell et al., 2005; Phillips et al., 2007). This work is however still fragmented and theoretically under-developed. Within marketing, over the last 10 years or so, scholars developed an approach to markets which emphasises the active production of markets, and suggests that firm success is achieved not only by adapting to markets but also to changing markets (Kjellberg et al., 2015, 5). Markets are seen as “social constructions co-created by market actors as they engage in market practices” (Storbacka and Nenonen, 2011b, 255). Within this relational perspective, “sustainability journeys are no longer a matter of shifting from one equilibrium state to another, but the continuously negotiated accomplishment of an assemblage of humans and things involving deviation and contestations” (Garud and Gehman, 2012, 984).

We draw both on marketing and PSM research to review how market actors can respond individually or collectively to supply

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uncertainty which affects innovation adoption. First, we review the literature which suggests sourcing strategies for firms operating in 'market-taking' mode. Then we describe the 'market shaping' perspective in more detail, before summarising market shaping processes to bring the discussion back to specific measures.

5.1. Market taking sourcing strategies

Here we review the literature and practice we identified that relates to market-taking sourcing strategies to mitigate supply uncertainty: collaborative relationships, long term contracts and use of intermediaries, and consider possible implications for market evolution and dynamics.

Many authors suggest close relationships with core suppliers are necessary when setting up a new supply chain. Golicic and Sebastiao (2011) and Sebastiao and Golicic (2008) indicate that having a small group of suppliers and buyers, and the sharing of resources, are crucial in the early stages of product development, although these can lead to high interdependencies. Gold (2011) highlights the importance of trustful cooperation and the usage of synergies among suppliers and plant operators in the bioenergy context. In fresh-produce and agri-food supply chains, Hingley (2001) finds that selecting fewer but significant suppliers can be a good solution. According to Stevenson and Spring (2007) in a successful, proactive supply chain, it is necessary to reduce uncertainty while increasing flexibility, This can be achieved through collaborations with core suppliers to increase efficiency in the product design process and minimise risks. Long term, though not necessarily collaborative, relationships are commonplace in the energy from waste (i.e. incineration) sector, where many plants have been funded under private finance initiative arrangements (National Audit Office, 2009).

Collaboration makes good sense in a closed loop setting where mutual adaption can be negotiated and all parties share an interest in enduring arrangements. Uncertainty is reduced through having fewer actors and known interdependencies. Value distribution among network members is necessarily explicitly addressed in setting up the system. In the case of 'open' supply systems however the case for feedstock suppliers entering long term supply arrangements seems less favourable since, as highlighted in Section 3, they can expect the value of feedstock to rise.

For both partnerships in closed loop arrangements and very long term contracts, the buyer's response to uncertainty is to *guarantee supply* – without assured supply, there would be no BfOR plant. These quasi-vertical integration strategies could lead to fewer, larger, and longer-term contracts for BfOR feedstock. Reduced contract turnover is however associated with market lock-in, limited price competition and reduced innovation. (Caldwell et al., 2005).

An alternative approach, identified in Oglethorpe and Heron's (2013) and Hingley et al. (2010) studies, is for a BfOR plant buyer to reduce uncertainty in feedstock supply by meeting its needs through an intermediary. If demand for feedstock were to rise, intermediary business such as pre-treatment and logistics services would become increasingly attractive. In contrast to the strategies above, if using independent intermediaries were the dominant response to feedstock supply uncertainty, this would be an attractive market for new entrant intermediaries, potentially made even more attractive by policy changes such as rising landfill tax and renewable energy incentives. In this scenario, increasing numbers of intermediaries, lower switching costs, shorter term contracts, and price-based competition could lead to market fragmentation and critical shortages as well as price volatility (Breen, 2008) and lack of innovation (Walker et al., 2006). Lack of security of supply could lead to BfOR plants competing for scarce feedstock resources with recycling facilities thus potentially driving up feedstock prices and reducing recycling rates – an absurd outcome from an environmental perspective. These sourcing strategies align with resource dependence theory which points to forming alliances or collaborations with key players, such as customers (Pfeffer and Salancik, 2003) or suppliers (Hessels and Terjesen, 2010) to reduce dependency and risk by acquiring key resources, leading to greater control by the plant operators (Shook et al., 2009). The associated scenarios for the evolution of the feedstock supply market suggest however that short-term and local efforts to address supply uncertainty may cumulatively, and over time, be counterproductive (Caldwell et al., 2005).

5.2. Shaping the market: strategies, processes and practices

Efforts by policy makers, new entrants and incumbents to shape the demand-side of the renewable energy market are central to sustainability transitions research on the energy sector (e.g. Verbong and Geels, 2007). In contrast, there appears to be very little academic work on efforts to shape upstream markets, despite supply market capacity and capability being recognised as critical constraints to progress towards renewable energy (e.g. BVG Associates, 2012). Capacity (in terms of resources, including market power) and capability to shape markets vary across contexts. In sectors such as offshore wind and electric vehicles, many firms are large organisations diversifying into the sector. In other sectors however such as BfOR and agri-food there are typically many smaller projects, with little scope for influencing market evolution if acting alone. Given our focus on BfOR and on PSM, in this section, we concentrate on the role of feedstock *buyers* in influencing the structure and dynamics of the market through their sourcing decisions and strategic development, paying particular attention to collective efforts to shape markets. As above, we draw on innovation literature (see Table 1, stage 2) more widely, not only related to sustainability.

Within the PSM field, public procurement research has provided valuable insights on strategic action to alter markets (Ulkuniemi et al., 2015), to advance policy goals, promote a competitive set of supply alternatives (Caldwell et al., 2005) and incentivise investment and innovation (Uyarra and Flanagan, 2010). Supply alternatives and innovation can be generated by encouraging new suppliers to enter the market, or reducing the number of suppliers in the market (Caldwell et al., 2005; Walker et al., 2006), sometimes through the agency of a third party such as a national buying agency or campaigning organisation (Phillips et al., 2007), or sometimes through buyer–buyer collaborations (Essig, 2000; Schotanus et al., 2010; Walker et al., 2013). The underlying logic is that it is in buyers' interests to have supply markets in which suppliers compete on price and quality in ways that lead to relative stability, providing predictable and sustainable markets at the collective level but dynamism at the level of contracts and relationships between specific buyers and sellers, with switching between sources encouraging innovation. Fragmented markets characterised by price wars or volatile prices, low margins and lack of innovation are no more attractive than static, monopoly markets.

PSM research on buyer–buyer collaboration in the context of innovation in the commercial sector is less common (Ulkuniemi et al., 2015). Herlin and Pazirandeh (2012)'s research shows how NGOs acted to increase their purchasing power within humanitarian supply chains. They describe "market shaping" initiatives in vaccine supply chains. In the agri-food sector, Banker and Mitra (2007) make the case for implementing IT based applications to link growers to international and domestic markets to reduce both the costs of transactions and risk, so that buyers are more willing to try out new suppliers. Based on case studies of nascent market Golicic and Sebastiao (2011) argue the supply chain strategy should be able to

Table 3
Summarising key insights on measures managers may adopt to shape markets in innovation settings, based on recent research on 'market innovation' (Industrial Marketing Management, 2015).

Onyas and Ryan (2015): Through exploring the transition of a coffee market in Uganda from a mainstream market to a sustainability market (Fairtrade, organic certification), the authors frame the actualising of ongoing market innovation as *agencing markets*. They observe two types of strategic effort by the focal actor, the coffee exporter: "prosthetic strategy" and "habilitation strategy" (Callon, 2008), where the former concerns "equipping farmers to play their part" (Kjellberg et al, 2015, 6) and the latter is about "creating an environment conducive" (Kjellberg et al, 2015, 6) to farmers adopting the higher value added and more sustainable processing option.

Storbacka and Nenonen (2015): These authors develop a model of market learning. Based on a case example, they show how market innovation is about recognising and influencing – but not necessarily initiating – the various stages and processes in the learning cycle: trigger; ORIGINATION – analysing, modelling; MOBILISATION – testing, applying; STABILISATION – reflecting, consolidating (2015: 77). Thus the focus is on sense-making as advocated by Möller (2010) rather than directing market change

Ulkuniemi et al., 2015: five types of actions identified:

Market-shaping actions	Illustrative actions
Supply-shaping	Participation in industry standardisation effort Perceiving and defining the industry supply
Demand-shaping	Participation in industry standardisation efforts Monitoring other buyers in the market to compete or co-operate Meaning attached to competitors'' use of the same component (sign of quality or trade secret risk)
Need-shaping	The identification of the own need based on existing offerings or own system requirements Communicating the need to the potential suppliers
Exchange object-shaping	Defining the product and associated services through characteristics of component or through solution that the component offered Forming a joint understanding with seller
Exchange mechanism-shaping	Defining the nature of the exchange mechanism Managing the supplier relationship

They recognise that "coordination and/or cooperation between buyers can help homogenise the market but the emerging phase of a market can create conflicting interests too strong to overcome. In particular, in high-technology settings, concerns about protecting core technologies can foster more heterogeneous demand." (p60).

shape market demand rather than respond to it – a point echoed in supply risk research, where Li and Barnes (2008), Giunipero and Eltantawy (2004) and Zsidisin et al. (2004) highlight the importance of proactive – rather than reactive – risk management in the supply chain. Chiffoleau (2009), an economic sociologist, examined (dis) embeddedness among networks of producers in alternative food supply chains, demonstrating ways to take account of social and political ties – not just economic/commercial links – between actors, and how these underpin collective action in the formation of new supply chains, networks and markets. There are examples in the literature of cooperatives working together to supply biomass (Cato et al., 2008; Downing et al., 2005), rather than purchasing it. These biomass vendor cooperatives are independent of the energy generator and are an intermediary between the buyer and the supplier. Such cooperatives are a form of intermediary which, if operating on a commercial basis, is more akin to social than commercial entrepreneur (Santos, 2012).

The emphasis on embeddedness is also apparent in Möller's article (2010) on sense-making and agenda construction in emerging business networks. This presents a 'business emergence framework' which brings together IMP-rooted business network thinking with the multi-level perspective of innovation in sustainability transitions. The framework combines business fields as 'landscapes' and networks of key actors, both those directly involved in the supply chain (suppliers, producers, and consumers) and other stakeholders (industrial bodies, financial institutions, and research organisations). Thus the framework helps to link the wider business context with a network perspective of more local developments, recognising both supply chain actors and other stakeholders, and complexity, novelty, dynamics and embeddedness. The premise of Möller's argument is that better understanding can enable agenda construction and this perspective "sensitizes management to the political and power-related character of the networked creation of a new business field" (Möller, 2010, 369). Agenda construction is also central to Storbacka and Nenonen's concept of market scripting: "the conscious activities conducted by a market actor in order to alter the current market configuration in its favour", where the configurative elements are mental models, business models and processes/practice (Storbacka and Nenonen, 2011b, 259).

Whereas PSM research provides insights on market shaping *strategies* in response to supply uncertainty, we found marketing scholars offer greater insights to market shaping *practices* and *processes*. A recent special section of Industrial Marketing Management (January 2015) addresses 'market innovation' processes – processes leading to "successful change of existing market structure, the introduction of new market devices, the alteration of market behaviour, and the reconstitution of market agents" (Kjellberg et al. 2015, 6). Whilst only one paper specifically adopted a purchasing perspective (Ulkuniemi et al., 2015), several address supply side, buyer-led processes, providing insights to practical measures (strategies, processes, practices) PSM managers might adopt, as summarised in Table 3.

Past research on buyer–buyer cooperation is valuable and highly relevant, but is centred on buyer decision making and interventions rather than extending to detailed study of market evolution (Ulkuniemi et al., 2015). Buyer–buyer cooperation in response to BfOR feedstock supply uncertainty would increase buyer market power (Bakker et al., 2008; Palmer, 2002; Schotanus et al., 2010) but the diversity of technical requirements and small scale of many BfOR plants suggests more, lower value contracts and a lower risk of lock-in than in the case of large-scale incineration plants operated by international firms with very large long term feedstock supply contracts with, for example, municipal authorities. Buyers might coordinate purchases, or information about purchases, or both, to gain visibility of market developments and so to influence the structure and evolution of the supply market with the goal of ensuring a sustainable and competitive supply market (Caldwell et al., 2005; Walker et al., 2006).

In summary, our review of past research which helps to address the question of what measures might be adopted in response to supply uncertainties which constrain innovation indicates there are several local interventions organisations may take in a responsive (market-taking) mode, but these may cumulatively prove to be counterproductive. Prior research in public procurement and more recent studies in industrial marketing indicate alternative

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responses in which buyers seek to influence the evolution of their supply markets to facilitate the innovation adoption.

6. Conclusions

This exploratory paper takes as its starting point a practical problem: promising, innovative sustainability initiatives may not be widely adopted because the commercial context includes supply-side constraints which discourage investors. This issue is framed in terms of two research questions: in the context of sustainable transitions, RQ1) how does supply uncertainty constrain innovation adoption, and RQ2) what measures can be taken to address supply uncertainty when it constrains innovation adoption? Through an extensive, iterative review of the literature, we reach five key conclusions about the nature of the problem and ways in which it might be addressed. The first two relate specifically to RQ1, the third to both research questions, and the fourth and fifth to RQ2. These demonstrate the relevance of prior research, but also its limitations, and provide the basis for proposing future research following two themes, relating respectively to the first and second research questions. Finally, we discuss the theoretical and methodological implications of our findings, and their implications for policy and practice.

First, that sustainable transitions, such as the advent of renewable energy, are distinct empirical settings in which to study innovation and supply. PSM research is needed to complement well-established streams of research on sustainable supply chains within existing business systems and new product development. Second, as advocated by Pagell and Shevchenko (2014), this research should consider highly diverse actor motivations, not simply focused on profit maximisation, and their consequences for responses to uncertainty. Third, in exploring the sources of uncertainty, we note how uncertainties related to market structure may be beyond the scope of the influence on individual buyers in the system. Horizontal collaborations and intermediaries, for example, are needed to open new routes to market, or to encourage supply (or demand). Fourth, supply uncertainty can slow or block the co-evolution of supply and demand. Such market bottlenecks or market deadlocks are a form of market failure but, when upstream, they may be out of scope for public procurement interventions. The subsequent discussion of strategies, practices and processes in response to uncertainty draws on public procurement research, but highlights the limited reach of public procurement interventions to promote innovation Fifth, we find that the risk-mitigating, market-taking sourcing strategies of vertical partnerships and buying through independent intermediaries could prove counter-productive, by generating new market uncertainty. Finally, we explore opportunities for reducing supply uncertainty by actively shaping markets, recognising that buyer–buyer cooperation may be necessary.

Bringing together the BfOR feedstock supply problem and insights from the literature, we show that sustainability transitions need sustainable supply markets, and yet that upstream supply markets are (relatively) neglected in the ST literature. Likewise, PSM research on market shaping has not extended beyond the public sector, and it has been focused on interventions rather than directly addressing consequences for markets and innovation uptake.

We therefore propose two related themes for future research. Both themes are considered in the context of sustainability transitions, where transformative change is needed and supply uncertainty is very high. First, relating to RQ1, the basic premise of this paper needs to be evaluated, to verify the nature and impact of the market deadlock/bottleneck problem in relation to supply uncertainty. The line of inquiry on market deadlock would be a critical, empirical evaluation of the phenomenon, its occurrence across diverse socio-technical regimes (e.g. electric vehicles, different forms of renewable energy) and at different stages in supply chains, and its impact. Where supply uncertainty is found to lead to market deadlock, or to act as a significant barrier to innovation adoption, more detailed investigation of the sources of uncertainty would be valuable. A challenge here would be gaining sufficient access to market stakeholders, and developing a robust account of a market's evolution, to support explanatory analysis.

The second theme relates to RQ2 and concerns addressing market deadlocks/bottlenecks, by attempting to resolve them through market shaping/innovation, or by adopting risk-mitigating sourcing strategies, or both. Through comparative analysis of cases of supply market deadlock and bottlenecks and supply uncertainty, several questions can be addressed, including:

- What supply market interventions and arrangements (structures, collective strategies and common practices) are deployed to address market deadlocks and bottlenecks associated with high supply uncertainty? How and why do they vary?
- Which actors lead interventions and shape arrangements? How do they do so? In particular, what role(s) do intermediaries play, whether independent or cooperation based, and commercial and social outcomes based?
- To what extent are interventions and arrangements effective? Effectiveness can be considered in terms of impact on the perceived deadlock or bottleneck and on innovation outcomes.

As with the first theme, methodologically such research is highly challenging due to the scale and complexity of building a market level, longitudinal case. Industrial Marketing Management authors (see Table 3) have successfully used workshops as well as interviews and documentation for processual-oriented investigation of market innovation, but all used single cases. Alternatively, prospective, participatory research could provide the necessary access and oversight, staying close to developing practice (Pagell and Shevchenko, 2014). Scaling up resources may prove to be a critical constraint to comparative research, which would need to provide both a 'close-up' view of process, and a long term perspective to complement the timescales of market evolution.

This agenda also presents some critical theoretical choices. Resource dependence theory is widely used in considering firms' responses to risk and uncertainty (Hillman et al., 2009; Chicksand et al., 2012), and would serve as a good basis for a firm centred perspective of sourcing strategies and practices. Market innovation studies (see Table 3) adopt a relational perspective inspired by the work of Callon, among others (Garud and Gehman, 2012; Araujo, 2007). This differs from the relational view of buyer–buyer collaborations advocated by Walker et al. (2013), which extends the resource based view to interorganizational networks.

The relevance to policy and practice of this article is clear, given its roots in a practical problem. It relates to the early phases of market uptake of innovations, in the 'valley of death' zone in the commercialisation process (COWI, 2009). A particular concern for policy makers is how to scale up /roll out initiatives, beyond demonstrator and early adopter projects. Government programmes are promoting research and development across supply chains,[3] but supply markets receive little attention. This possibly reflects a reluctance to be seen to be influencing markets grounded in concerns about anti-competitive practices (e.g. Mazero and Loonam, 2010; IRM and CMA, 2014). The boundary between effective collaboration to promote transformative change

[3] See for example a recent call (Feb 2015) from UK government programme on 'Integrated supply chains for energy systems' to "to encourage cross-sector supply chains that can deliver integrated energy solutions at different scales" at https://interact.innovateuk.org/-/integrated-supply-chains-for-energy-systems.

and collusion for private gain is not self-evident when attempting to predict long-term, complex system level change. Legitimacy and collusion (Pressey et al., 2014) will be critical themes within the research outlined above. At the level of management practice, the case for market shaping and buyer–buyer cooperation raises issues of personnel and organisational capability (Möller, 2010).

Despite its importance to the sustainability agenda and innovation, PSM research related to supply uncertainty in nascent markets is limited. Though widely dispersed across several disciplines, several sources call for further research on how emerging markets can be shaped, and a balance between market dynamism and stability sustained. Mapping, predicting and influencing the evolution of markets is a supply management topic that is relevant wherever there are systemic commercial barriers to adoption of innovation despite demonstrable social and environmental benefits. Our analysis points to the potential importance to buyer cooperatives and other forms of supply market intermediaries. Based on the example of bioenergy from organic residues described above and the subsequent analysis of prior research, we conclude that developing our understanding of how to engender sustainable markets despite high supply uncertainties is vital to the sustainability agenda. The evolution of sustainable markets is a supply management issue which warrants considerable further research, despite the many challenges this presents.

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