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From best practices to bridges for a more sustainable future: advances and challenges in the transition to global sustainable production and consumption

Introduction to the ERSCP stream of the Special volume

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ABSTRACT

This stream of the special volume addresses advances being made towards, and challenges for sustainable production and consumption. The article presents a variety of papers that document leading examples of recent developments in understanding and knowledge, before assessing gaps within current progress and posing questions and challenges for future research and practice. An overview framework is constructed to categorise the papers, and to illustrate key actors and factors for sustainable production and consumption. The themes covered include specific examples of progress in areas such as sustainable production, covering topics such as eco-efficiency, waste management and the use of renewable resources, as well as sustainable consumption and the role of consumers. Supporting actions and themes are included, showing recent advances in design and innovation for sustainability and the role of assessment and benchmarking. Finally, contributions that consider how to connect production with consumption, and upscaling and bridging, are examined. The article concludes by proposing that continued progress is reliant on further connecting production and consumption, and ensuring that consumer and user perspectives are integrated into innovation and design processes so as to overcome hindering factors such as rebound effects. A call for further progress is issued on what needs to be done to go beyond 'good examples' and on what actions and strategies are able to share and spread success stories of sustainable production and consumptions to different contexts and settings.

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1. Introduction to conference and topics

Current modes of production and consumption have resulted in unsustainable economic, social and environmental outcomes (Clark, 2007). Many Earth system processes, ranging from climate change and biodiversity losses to mismanagement of the nitrogen and phosphorous cycles, have reached or have surpassed their

biophysical limits due to human activities (Rockstrom et al., 2009). We have also undermined the resource base our industrial system relies on with severe material scarcities foreseen in the near and medium-term future with significant implications on the manufacturing capacity (Gordon et al., 2006; Schoolderman and Mathleener, 2011). Although the recent financial crises may have contributed to lower economic activity and lower environmental impacts in the developed world, they have hampered sustainable development initiatives, with the levels of inequality between and within nations rapidly becoming more extreme (United Nations, 2013).

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The current unsustainability of modern systems of production and consumption requires a substantial transition in order to become sustainable (Grin et al., 2010). Changes and progress will be required in a wide variety of disciplines and approaches (Reid et al., 2010). New and improved production techniques and processes are demanded, and the businesses and organisations that control them must change the manner in which they operate (Michaelis, 2003). This will have to include new business models and advances in management approaches, including new ways to judge business performance and success (Loorbach and Wijsman, 2013).

Innovations at all levels are essential to help to catalyse and support these advances and improvements, and they must also be examined when considering a transition to more sustainable forms of production and consumption (Leach et al., 2012). The tools and methods required will include new assessment and measurement approaches and techniques that effectively document inefficient and unsustainable aspects of production and consumption and support their replacement by policies (Perrini and Tencati, 2006; Rotmans, 2006). These approaches are required to support production and consumption patterns that are sustainable and equitable.

The need for changes has led to new thinking and approaches in terms of transitions; these include how best to conceptualise and understand the way different systems undertake change and the role of different factors, such as innovations or policy, play in these processes (Elzen et al., 2004; Geels, 2005; Smith et al., 2010). Such approaches allow large-scale systemic changes, in areas such as energy and food or transport, as well as addressing how social and technical developments interact (Elzen et al., 2004). This has led to the development of co-evolutionary frameworks, that attempt to consider how technologies, business models and user practices change together, and the multi-level perspective that seeks to consider changes at the micro, meso and macro levels, gaining prominence in both policy and academic discourses (Foxon and Pearson, 2008; Geels, 2005; Smith et al., 2010).

The papers selected for this stream of this Special Volume (SV) of the Journal of Cleaner Production provide contributions in many of the areas requiring such transitions. The papers included address particular aspects of sustainable production and consumption. The themes of this SV stream are introduced, and the key contributions of each of the papers within each theme are highlighted.

The papers are divided into those that address the production side, those that focus upon the consumption side and those themes that support the transition to sustainable production and consumption; i.e. by looking at production and consumption activities as closely interlinked elements of a system. The divisions are illustrated in Fig. 1, and include:

- The production side, including examples of *eco-efficiency*, *waste reduction* and the use of *renewable resources*. The theme dealing with *firms and organisations* is also situated here;
- The consumption side, including the drivers for the consumption of green products by *consumers*;
- The role of *design and innovation*, as well as those processes that seek to enhance user perspectives in design and innovation via the *connection of production and consumption*.
- The role of *assessment and benchmarking*; and
- A theme addressing actions that are able to spread examples of sustainable activities via *bridging and upscaling*.

Starting on the production side, the first theme provides examples of advances in the sustainability of production processes and of the products produced; this area deals with the concepts and practices of eco-efficiency, waste management and renewable resources. Then the firms and organisations, which control and

implement the processes and services, are addressed. These contributions highlight new ways of thinking about firms and organisations for sustainable production and consumption, and the role that firms and organisations play in the transitions.

On the consumption side are papers that consider motivations for sustainable consumption. Linked to this theme are several papers that deal with how to connect production and consumption, including through the integration of user perspectives into design and innovation processes.

Design and innovation processes themselves form a specific theme within this stream of the SV, covering issues such as drivers for eco-innovation and methods for integrating sustainability criteria into design processes. The key questions addressed by the authors in this group of papers focus on ways to incorporate sustainability criteria and objectives into the design and innovation processes of sustainable products and services.

Separate from these themes, but in many ways linked to all of them, is the issue of assessment and benchmarking. We conceptualise assessment and benchmarking as supporting the other themes in providing the information and data on the impacts and results of new designs and innovative processes. The monitoring of products, processes, systems and organisations is a key requirement for learning processes that are essential for catalysing the transition to sustainable production and consumption.

The last theme that is addressed in this portion of this SV is focussed upon bridging and upscaling; the papers within this topic focus on methods for spreading examples of actions that enable sustainable outcomes, either between/among actors or organisations or between/among regions or societies. This theme considers questions focused on how to take good examples of progress towards sustainable production and consumption and to build upon them. This can be seen in two senses, firstly expansion via upscaling and secondly, in terms of transferring these examples to new contexts and settings via bridging. A map of the main themes addressed in this SV stream are presented in Fig. 1.

2. Key themes and factors for sustainable production and consumption

The contributions within this SV stream cover a wide variety of themes and topics, which are, nonetheless, inter-connected (see Fig. 1). The figure shows the interconnections among the themes in a simplified way by highlighting the interlinked roles and positions of firms, organisations, consumers and the supporting processes of design, innovation, assessment and benchmarking.

The transitions that are required to achieve more sustainable production and consumption systems will need advances across all these themes, including technological, managerial, organisational and behavioural aspects.

Products and process advances are required across countless areas, such as energy, transport, food systems and waste management; examples of these are illustrated first, using key concepts such as eco-efficiency and covering core topics such as agriculture, water and waste. These represent specific aspects of production, which were controlled and instigated by companies and organisations. Changes are also necessary here, in terms of how we conceive and theorise about organisations and in our understanding of how they select technologies or instigate eco-innovation. Businesses and organisations, responsible for the design and production of products and services, are increasingly sensitive to Corporate Social Responsibility (CSR) related reputation risks and are engaging with sustainability to an increasing degree, both internally and in their supply chains (Kolk et al., 2008; Kovács, 2008). Although much of this engagement is likely to be symbolic rather than substantive, it does represent a shifting of expectations

Fig. 1. This figure depicts the inter-related content foci of the papers included in this stream of the Special Volume.

and increasing dialogue and thought on sustainability and business (Barkemeyer et al., 2010; Rodrigue et al., 2013).

Over the last two decades, business focus on sustainability has certainly brought us cleaner and more efficient products and services. However, there is also a need to make fundamental changes to our business models – and the systems that support them – to meet our current and future sustainability challenges (Gaziulusoy et al., 2013; Whiteman et al., 2013). Business models approaches have been one approach in the attempt to improve our understanding of how businesses operate and how this can be altered to improve their sustainability performance (Boons et al., 2013). Interest in business models arose out of the dotcom boom of the 1990's, yet is now a well-defined area of research in terms of sustainable businesses (Bocken et al., 2014). This approach in researching and conceiving of sustainable businesses and its potential contribution to sustainable business is a useful link to other key concepts such as innovation (Boons et al., 2013; Lüdeke-Freund, 2009).

Consumers also represent a key area of action when considering the required shift to more sustainable production and consumption. There is debate concerning the relative level of understanding and action in terms of production versus consumption (Stevens, 2010). In terms of sustainable consumption, understanding and action are more limited when compared to sustainable production (Vergragt et al., 2014). This side of the production–consumption equation is critical to the required transition to a more sustainability future, as many gains facilitated via technology are overtaken by increases in consumption (Midden et al., 2007). Governments have, in the past and now, been relatively reluctant to act against or regulate consumers to any great extent; although the

EU is now providing examples of a successful approach, through product choice editing, such as limiting the sale of lightbulbs, or through the rollout of energy efficiency labelling on white goods (European Commission, 2015; Geller et al., 2006; Kok and Jennen, 2012). Another bit of progress in this sphere includes the increasing use of popularity of behavioural economic approaches for policy making (Sunstein and Thaler, 2012); however, consumption is still mostly cost driven and a substantial shift is most likely reliant on individual personal actions (Steg and Vlek, 2009).

Examples of progress for sustainability are easier to identify on the production side. Within the wider field of sustainable consumption and production and as is presented in the papers of this SV stream, the spread of knowledge and action seems weighted heavily in favour of sustainable production (Vergragt et al., 2014). Governments have been active in varying degrees on the production side of the issue for many years, via policies and regulations, initially on pollution, spreading more recently to issues such as climate change and biodiversity (Dryzek, 2013; Harrison, 2001).

Some of the challenges that led to this situation may be due to sustainable consumption being less able to be impacted by technological advances, and is subject to factors such as the rebound effect, where advances in efficiency are often undone by corresponding behaviour changes (Jackson, 2006). Although many consumers in the West report their intention to consume in more pro-environmental ways, when this is compared to behaviour an 'Attitude-Behavioural Intention' gap is often found (Peattie, 2010; Vermeir and Verbeke, 2006). Efforts to understand why this gap exists, and how to ensure that attitudes, intentions and behaviours are aligned to sustainable outcomes are critical.

In order to move toward sustainable future societies, action is required in terms of both sustainable production, for instance through the improvement of production processes and technologies, and sustainable consumption. On the one hand, this justifies the breadth of topics that must be covered through research. On the other hand, it is increasingly acknowledged that sustainable production and consumption have to be addressed in an integrated and systemic manner.

Numerous examples exist of technological advances, from improvements in renewable energy technologies decarbonising electricity generation through to more efficient agricultural techniques; such examples are arguably most common in terms of production. The way that consumers interact with products and services is increasingly recognised as complex (Steg and Vlek, 2009). This leads to issues where technological advancement in production, can fail to deliver the reduced environmental or social impacts that were expected (Binswanger, 2001). This can be due to a lack of attention to the behavioural dimensions of consumption, such as the rebound effect (Robinson, 2004). Some designers and innovators are working to gain deeper understanding of how to influence consumer behaviour, through concepts such as user centred design (Wever et al., 2008), persuasive technology (Lockton et al., 2010), behavioural psychology (Zachrisson and Boks, 2012), and social practice theory (Kuijer, 2014; Pettersen et al., 2013). This requires higher levels of integration of technological and social perspectives and multidisciplinary work, and highlights why integrated action on the production and consumption sides is essential.

Sustainable production and consumption systems are more than the sum of their parts. Even when all parts show improvement, the whole system may suffer significant deficiencies. The ecological footprint of consumption is increasing despite consumers becoming more ecologically aware and production becoming more efficient (Lorek and Spangenberg, 2014). Systematic problems include rebound effect, increasing level of global carbon emissions due to delocalization of production (Schaltegger and Csutora, 2012), policy incoherency (Pineau, 2007) and conflicting consumer demands. Further research is needed for targeting these systematic problems.

Although some technological solutions may be consistent with the principles of sustainability because they deliver products and services with reduced impacts through their production, use and post-use phases, behavioural aspects such as the rebound effects can limit the environmental gains (Chitnis et al., 2013; Figge et al., 2014). The limitation of technological approaches, including the design and innovation processes, highlights a crucial role for behavioural and social contributions. One example of this is the impact that infrastructure and products can have on behaviour; where infrastructure or products are designed and integrated correctly, the rebound effect can be overcome, and in some instances pro-environmental behaviours can be achieved as a positive spill-over (Long et al., 2014).

Consumers demand sustainable products, safe products and more convenience at the same time. Conflicting demands may lead to awkward legislation such as the 'straight cucumber directives' of the EU or animal safety regulation like 'swine fever act', treating post-consumer food waste as hazardous waste instead of using it as animal feed. Thus, increasing eco-efficiency in food production can be coupled with elevated level of wasting on the consumption side (Papargyropoulou et al., 2014).

This underscores the need for holistically addressing design, production, consumption and post consumption management of products. Without these links and synergies, and where actions are isolated on the consumption or production side, sub-optimal outcomes may result. Measurement and assessment within this

context, whether it be at the product or organisational scale, is a key tool for transitioning towards more sustainable production and consumption (Dendler, 2014).

By developing and applying improved understanding offered through advances in measurement and assessment business, leading innovators can foster innovative design of products and services (Boons and Lüdeke-Freund, 2013), which can influence consumer behaviour, for instance via marketing and the provision of post-sale services (Bocken et al., 2014; Clinton and Whisnant, 2014). This perspective may lead to questions about the evolving roles of corporate CSR commitments and competencies for fostering sustainable production and consumption (Osagie et al., 2015), as well as how management and leadership can enhance pro-environmental behaviour in the workplace (Blok et al., 2015) and how to empower employees to adopt changed working routines due to the integration of sustainability (Verhulst and Boks, 2014).

Sustainability involves unique challenges due to multiple scales and objectives that must be taken into account when attempting to identify and to implement solutions (Munda, 2005). The content of Fig. 1 highlights the fact that there are many interconnections between sustainable production and consumption. These interconnections reflect on factors on the individual level, through to nations and international organisations. Due to these interconnections, it is critical that when identifying and implementing examples of sustainable solutions, they should reflect this interconnectedness. Consumption and production must be brought closer together, to actively support the incorporation of behavioural and user perspectives.

However, integrated approaches of sustainable production and consumption have implications for technological, economic, social and political aspects of contemporary systems. Each of these realms will be impacted by, and play a role in the transition to sustainable societies. Multiple sectors must be involved in the changes in production methods and consumption patterns in order to make lifestyles more sustainable.

An example of this need for integration is the concept of responsible research and innovation, which specifically attempts to address social-ethical issues like societal desirability, sustainability and ethical acceptability in innovation processes (Blok and Lemmens, 2015; von Schomberg, 2013). Another example of a method for integrating and connecting production and consumption is the concept of user-centred design, which is designed to incorporate user's wants, needs and limitations into each stage of the design process (Abrás et al., 2004). If approaches such as responsible innovation and user-centred design, which seek to harness innovation and design process, are combined with greater understanding around behaviour and sustainable consumption, such principles will help to narrow the gap between production and consumption. Similarly, co-creation, if harnessed towards sustainability, could result in significant advances, allowing consumers a greater role in the shape and development of products and services, and potentially greater benefits.

3. Key findings and insights from the papers in this stream

3.1. Products and processes for sustainable production and consumption

Within the articles dealing with products and processes for sustainable production and consumption, several sub-categories were identified, which include papers dealing with eco-efficiency, waste management and reduction, as well as with renewable resources.

Eco-efficiency is a central conceptual and procedural tool for helping leaders to make sustainability transitions, by producing

goods and services with fewer inputs and less manufacturing waste. [Mueller et al. \(2015\)](#) and [Mahallati et al. \(2015\)](#) used such methods for increasing agricultural productivity; they represent the first two of three contributions that use eco-efficiency in this section.

[Mueller et al. \(2015\)](#) assessed the sustainability of kiwi orchards in New Zealand by focusing on environmental impacts and resource consumption ([Huppel and Ishikawa, 2005](#)). While they highlighted the need for orchards to be profitable and socially responsible, the authors found that the eco-efficiency of organic orchards was significantly higher than that of integrated orchards; integrated orchards are those that take a science-based approach to fruit production, often utilising both biological and chemical inputs. A key contribution of their research was their demonstration that eco-efficiency approaches were able to enhance product differentiation for customers, and to help orchardists find the most sustainable management systems. This illustrated the value of the concept and its ability to impact not just production perspectives, but also those of consumers.

[Mahallati et al. \(2015\)](#) determined optimal approaches for intercropping in Northeast Iran; specifically, they experimentally determined the optimal strip width for maize/bean inter-cropping. When they compared this approach to monoculture agriculture, they found that inter-cropping resulted in higher total land productivity. Their paper documented that intercropping was more productive than monocultural approaches.

The third contribution in this section, related to the concept of eco-efficiency, was written by [Pehlken et al. \(2015\)](#). They investigated how to maximise energy efficiency in the processing of natural raw materials where uncertainties were created by natural variations. They highlighted that raw materials often contain irregularities, which prevents ideal processing in terms of energy efficiency. This is especially pertinent where weather can impact the quality of grain for human consumption or for animal feed. These differences can lead to non-uniform end products and sub-optimal processing, which negatively impacts the price and success of the producing firm; this can also lead to difficulties in product labelling or in assessing the greenhouse gas (GHG) emissions calculations. It is important to be able to document and quantify such uncertainties in the processing stage, which can result in more optimal processes and reductions in energy consumption. The authors developed a method for improving the measurement of energy use in their production processes where uncertainty is a problem, to support increased energy efficiency without compromising the quality of the product. Specifically, through a Monte Carlo simulation, they documented that by using a knowledge management system, with online quality control measuring devices, their production managers improved their production quality and efficiency.

The papers by [Mueller et al. \(2015\)](#), [Mahallati et al. \(2015\)](#) and [Pehlken et al. \(2015\)](#) illustrate the advances that are available through the concept of eco-efficiency as well as provide good examples of the specific advances that are being achieved within specific areas of production. These included alterations or advances in agricultural production practices, as well as in the processing of raw materials. This set of papers can also be seen to be focused on production activities upstream in the supply chain, dealing with either the production or processing of raw materials.

The reduction of waste is a central requirement in the transition to a more sustainable future. Several contributions dealt with this specific question. [Greco et al. \(2015\)](#) examined the drivers of solid waste collection via an empirical investigation in Italy; a sample of the waste management practices of 67 municipalities provided the empirical data. The authors found that economies of scale and cost

drivers differed between different types of waste, for example between paper, organic and undifferentiated wastes. Economies of scale were found to be strongest for undifferentiated waste. This could reduce municipalities' incentive to differentiate waste collection, which would have an impact on the percentage of the waste that is recycled. The authors recommended that efficiency could be increased via changes in the locations of waste deposit sites and by the frequency of collections.

Wastewater management was investigated by [Couto et al. \(2015\)](#) through examination of greywater treatment in airports. Greywater reuse is a key pro-environmental activity for households, industries and commercial buildings, but was quite uncommon within airports until recently. This is surprising, if we take the large quantities of water used in these facilities into account. The authors found that current available technologies, specifically anaerobic filtration followed by UV disinfection, pay off within five years. This is especially applicable for small and medium-sized airports, or in segregated facilities in large airports. The identification of cost effective approaches such as these is key to making progress in reducing wastage of water and the consequent costs.

Wastewater management was also investigated by [Siddique et al. \(2015\)](#), who analysed the feasibility of anaerobic co-digestion of activated manure and petrochemical wastewater in Kuantan, Malaysia. The authors highlighted that although anaerobic digestion has seldom been applied in petrochemical industries due to the long reaction periods, longer hydraulic retention times and a lack of process stability, their analysis showed that anaerobic co-digestion (ACD) could be effective. They calculated that the payback period could be as little as 3.75 years. This has positive implications for improving sustainability of petrochemical manufacturing.

The final paper of this section concerned with products and processes for Sustainable Production and Consumption, dealt with waste. It was written by [Patricio et al. \(2015\)](#), who assessed industrial waste management in the Lisbon Metropolitan area by using principles of industrial symbiosis and resource recovery and in-house reuse. Via material flow analysis, the authors identified and quantified the waste that was recovered. By comparing with information in a database of worldwide waste recovery cases, the authors identified recovery solutions and advances that could improve the system. Examples were found that could increase waste recovery from 79.1% to 93.6%. Further, they found that industrial symbiosis was more likely when organisations or facilities were located close to each other. That demonstrated a connection between the production of wastes and the potential users.

[Greco et al. \(2015\)](#), [Siddique et al. \(2015\)](#), [Patricio et al. \(2015\)](#) and [Couto et al. \(2015\)](#) offer contributions that highlight the importance of waste management for sustainable production; without progress in this area, and waste management activities in general, businesses throughout the supply chain, from upstream processors through to retailers, would have higher environmental impacts, with negative implications for sustainability. Advances in waste management include the ability to create value from waste and turn waste into inputs in production. As stated in a previous paragraph, these are also good illustrations of specific examples of sustainable advances in production, which are essential for moving towards a more sustainable future, and highlights the need to develop and test methods for expanding and spreading such examples.

The use of renewable resources, whether for the generation of energy or to substitute for scarce resource inputs in industrial processes, can be an important contributor to advances towards a sustainable future ([Rosenberg, 1993](#)). [Kimming et al. \(2015\)](#) compared methods for replacing fossil-carbon based energy in

the context of organic milk production in Sweden. Agricultural production, and in particular dairy and beef farming have substantial environmental impacts. As such, seeking to identify methods to eliminate fossil fuels from milk production would represent a step forward. The authors used farm sources of biomass to achieve self-sufficiency in fuel. Two biomass based systems were tested and compared with a conventional system. The conventional, fossil fuel based system assumed the use of conventional diesel, fuel oil for grain drying and electricity, produced in natural gas-fired large-scale power plants. The two biomass systems included a biogas system (based on manure and straw) and a second biogas system with manure combined with RME (rapeseed methyl ester) system. The two systems were compared with the conventional systems, which showed reductions of GHG emissions between 32% for the RMW system and 46% for the biogas system, compared to fossil-based systems. These are promising examples of ways to lower GHG emissions in the dairy sector.

Ciesielski et al. (2015) provided an overview of bacterial production of polyhydroxyalkanoates that can be used to replace petroleum-based polymers. The authors highlighted the potential of feeding polyhydroxyalkanoates producing bacteria on resources such as plant oils. This represents an advance, because it can avoid the negative environmental effects of petrochemically derived plastics, which depletes fossil fuel supplies, contributes to global warming and to also respond to the growing demands of an expanding global population, which is leading to increasing demands for plastics.

The paper by Sharma et al. (2015) presented results of pilot scale processing of agricultural solid residues for pulp and paper production. Specifically, the author investigated soda-anthraquinone pulping of palm oil empty fruit bunches and elemental chlorine free bleaching of resulting pulp using DEpD sequence. The authors compared their results with values obtained by other researchers using different processes at lab scale, and confirmed that operating conditions used through their study were able to be implemented at the paper mill scale. Their study confirmed that such approaches could be commercially viable, highlighting the value of examining the use of renewable resources in currently unsustainable areas of industrial production.

Kimming et al. (2015), Ciesielski et al. (2015) and Sharma et al. (2015) all deal with the use of renewable resources. Kimming et al. (2015) examined the potential of biomass fuel systems in milk production, which highlights the potential to integrate renewable systems into agricultural production practices. Ciesielski et al. (2015) and Sharma et al. (2015) are both able to demonstrate the possibility to substitute conventional inputs with those of a renewable nature. In order to create sustainable futures, the substitution of finite inputs into production processes must be substituted with renewable resources where possible. These three contributions highlight advances within this area, and again provide good examples of specific advances.

As with all the papers concerning specific examples of advances in sustainable production, they highlight that while such advances are evident within specific domains, they must be taken up by producers. But such examples must be adopted and then promoted so that they will spread and be expanded upon, a theme that is addressed later in this introductory article. At the core of these needs is the interconnected nature of sustainable production and consumption, which requires an integrated approach to achieve widespread adoption of these concepts and approaches.

3.2. Firms and organisations for sustainable production and consumption

Firms and organisations can be conceptualised as agents that implement and control production processes; this is because they

are often the actors that commission the production of goods and services in response to actual or perceived market demands (Michaelis, 2003). As such, they have a critical role in advancing sustainable production. At the same time, the firms downstream in the supply chain are close to consumers and are therefore, often in a position to influence consumption behaviours. Several contributions are included in this SV stream, which advance our understanding of the concepts and roles of firms and organisations in sustainable production and consumption. It should be remembered that firms and organisations are often the actors that control production, and to move towards a sustainable future, must identify and choose sustainable modes of production.

The paper by Lozano et al. (2015) presented a review of mainstream 'Theories of the Firm' and their potential contributions to understanding firms' roles in sustainability. The authors started from the premise that firms need to move away from short-term, profit driven approaches to long-term sustainability management of the firm. Using the concept of corporate sustainability, which is designed to provide holistic and balanced management of firms in terms of economic, social and environmental objectives, for this generation and future ones, the authors examined the limitations of current theories of the firm to deal with sustainability. To overcome these limitations, a Sustainability Oriented Theory of the Firm was proposed with the objective of helping stakeholders and leaders understand key obligations, opportunities, relations and processes. By increasing understanding in this way, the authors highlighted the key factors relevant to sustainable business operations, and therefore increased the likelihood of being able to motivate and enhance businesses to positively contribute to sustainable production and consumption, for example through the selection of sustainable production methods.

Based on the example of ballast waste water treatments, Hermann et al. (2015) examined how business models impact firm's usage of eco-innovations and their contributions to the diffusion of environmental technologies. In this article, a business model noted for its sustainability potential - product-service system (PSS) - was applied in the context of the maritime industry. Through the development of a conceptual framework and two-case studies, the authors examined the efficacy of different business models for ballast wastewater treatment systems. Using an Eco-costs/Value Ratio model, the authors compared on-board and port-based ballast wastewater treatment systems, with the aim of proposing a PSS. The authors found that port-based ballast wastewater treatment systems have the highest potential for eco-efficient value creation, and that a PSS could be envisaged for this type of technology. However, it was also noted that authorities should improve current regulations in order to stimulate port-based, rather than on-board systems. Contributions such as these product-service combinations highlight that firms and governments must co-work to help society move towards sustainable production and consumption.

Whilst the way that businesses are designed has an impact on how they relate to sustainability, Wesselink et al. (2015) examined the individual competencies required by managers to achieve sustainable outcomes in their specific contexts. The authors also examined at what stage in the implementation process they were important. These competencies are crucial in terms of managers' ability to devise and shape solutions to sustainability issues. By interviewing CSR managers at four large multinational enterprises, the research found that managers undertook four core tasks for CSR, including orientation, reaching common ground, performing pilot projects and embedding results. These tasks required competencies such as Systems Thinking, Embracing Diversity and Interdisciplinarity, Interpersonal Competence, Action Competence, and Strategic Management; Interdisciplinary competence and

embracing diversity were identified as the most important. This paper was able to highlight the importance of individuals, and how their skills and competencies can affect how organisations and businesses engage with, and act on sustainability.

Kucuksayrac (2015) examined the factors that drive organisations to design sustainable products and services in manufacturing and packaging firms in Turkey. By taking the best performing companies, the authors identified key drivers such as brand and reputational drivers. Unexpectedly, the potential of exports was not confirmed as a key driver. Lack of demand from consumers and regulations were found to be the biggest barriers. In a wider sense this author offered a valuable perspective, in that they highlighted the roles played by designers and innovations in advancing sustainability; this perspective is addressed further in the 'Innovation and Design Approaches for Sustainable Production and Consumption' section of this paper, but here it serves to remind us that single actors are often unable to achieve sustainable outcomes.

A key theme within the wider sustainable business topic focussed upon the relative performance of pro-environmental firms compared to firms that do not engage with sustainability (Arendt and Brettel, 2010; Falck and Heblich, 2007). Previous research has provided a mixed picture; some studies have noted improved performance with CSR, whilst others fail to replicate such results (Arendt and Brettel, 2010; Carter et al., 2000; Elsayed and Paton, 2005). This comparison was made by Marti (2015), via an examination of the performance of the financial performance of Spanish pension plans. The authors examined whether there was a difference in the financial performance of solidarity, ethical and traditional pension plans. They found that ethical pension plans performed as well as traditional ones, while solidarity plans slightly outperformed both. The paper highlighted the roles that investors can play in driving sustainability within companies, which is especially relevant given the authors' observation that socially responsible investing tripled between 2007 and 2011 in Europe. This can lead companies to work to reduce emissions, water usage, energy consumption and waste. So getting pension plans to integrate sustainability concerns into their investment strategies, could enhance firms' efforts, and their performance, and hence the performance of the pension funds. This serves to highlight that where businesses attempt to operate sustainably, they and others, can be rewarded.

A further contribution in this SV to the role of businesses and organisations in sustainable production and consumption was written by van Loon et al. (2015), who explored the logistical and supply chain aspects of sustainable production and consumption in the fast moving consumer goods industry in the UK. The authors analysed online retailing, a relatively new form of business, which can reduce environmental impacts. The authors developed a framework and associated life-cycle analysis model to take a wider set of variables into account compared with previous research, including customer use of information and communication technology. The results indicated that the 'last mile' link to the home is the most energy-intensive aspect of the supply chain. The key contributing factors that impact the environment include the nature and routine of van deliveries, the amount and type of packaging, and the energy efficiency of shops and e-fulfilment centres. Beyond the provision of recommendations to increase efficiency, and hence to reduce GHG emissions, the authors noted that consumer behaviour can be a critical aspect of the overall environmental impact of a consumer goods supply chain. This is an important insight, as it shows that attention must be paid to both production and consumption for sustainability, and again illustrates the necessity of bearing in mind the interconnectedness of sustainability.

Firms play a key role in production processes, by the selection of technologies they use to produce their goods and services (Shehabuddeen et al., 2006). Xia et al. (2015) examined the link between green technology selection and firm performance based on an empirical sample from China. The authors found significant inter-relationships among factors such as stakeholders, markets, financial and social dynamics, as well as policies on the choice of green technologies by firms. Supportive stakeholders and the market environment were important for the selection of green technologies. Macro-conditions, such as legislation, were found to have a background effect. This has important implications for policymakers seeking to enhance the adoption and use of green technologies, and demonstrates the key roles that businesses play in production decisions and patterns. It also highlights that many actors are relevant for businesses when taking such decisions, which is an additional reminder of the ineffectiveness of focussing on single actors when attempting to move towards sustainability.

3.3. Consumers and promoting sustainable consumption

The consumer perspective in this SV stream was addressed by Ritter et al. (2015). The authors examined the motivations for promoting the consumption of green products in the context of an emerging economy. As green consumption represents less than 4% of global consumption, strategies are required that will increase this, especially as emerging economies increase in affluence and their citizens aspire to a western lifestyle. Their research analysed the drivers of green consumption among consumers in Brazil's largest southern city who had previously bought green products. The results highlighted that information and knowledge, environmental attitudes, social contexts and environmental consciousness were all strongly correlated with green consumption. This indicated that education should play a central role in boosting green consumption; this emphasis links well with the other half of this SV stream concerning sustainability and education. The authors also highlighted the importance of the consumption side in terms of sustainable production and consumption, and that even where advances are made in terms of production, that if demand does not exist for such products or services, little impact in terms of sustainability would be made.

3.4. Assessment and benchmarking methodologies for sustainable production and consumption

Assessment and benchmarking provides the information necessary to help develop successful strategies for cleaner production and consumption (Perrini and Tencati, 2006; Rotmans, 2006). Without these methods, decision-makers would be unable to compare different strategies and to make suitable choices in terms of sustainability.

Mohammadi et al. (2015) synthesised two assessment methods in their consideration of the eco-efficiency of rice-paddy fields in Iran. Joint Life Cycle Assessment and Data Envelopment Analysis were used to benchmark and compare the environmental impacts of different production approaches. This method was found to successfully differentiate the environmental impacts of different operations types, thereby highlighting the most pro-environmental approach.

Environmental impact assessments (EIA) is a widely used decision-support tool, but there are many who criticise EIAs due to their site-specific approaches, lack of consideration of alternatives and unclear methodology of impact evaluation (Pope et al., 2004). Židonienė and Kruopienė (2015) integrated EIA with LCA to overcome these drawbacks, and to demonstrate their complimentary aspects. They applied their method to an

industrial project to identify opportunities to reduce negative impacts. Through this combined approach the authors highlighted potential reductions of 40% on human health risks and 20% reduction in resource usage. This paper highlighted that the development of this new measurement approaches enables decision-makers to identify previously unseen opportunities for cleaner production.

Lage et al. (2015) developed an hourly-based model for improving the monitoring of natural and alternative water resources. The authors documented that their model improved the ability of managers to monitor, analyse and forecast their water demand. The results of their research demonstrated that the model is a tool for quick analysis: this can result in better regulation and pumping schemes, for planning and design, system performance, and the identification of network failures.

Without the advances in sustainable production, for example, those developed by Mohammadi et al. (2015), Lage et al. (2015) and Židonienė and Kruopienė (2015), producers would be less able to highlight the most sustainable options; in turn, this shows that producing agents, be they firms or farmers, need support (and are unable to act alone), in their efforts to move towards sustainability.

The remaining two papers in this section on assessment approaches for sustainable consumption and production investigated energy generation. Although the approaches used in these papers were not new in themselves, they were applied to new contexts and highlighted previously unrecognised opportunities for improving the sustainability of energy systems.

Atilgan and Azapagic (2015) analysed the LCA of fossil fuel electricity generation in Turkey and demonstrated that for 10 out of 11 impacts, natural gas is the least harmful fuel, apart from ozone depletion impacts. Their analysis also highlighted that power plant operation and fuel transportation have the highest impacts. The authors, using the information gleaned from the LCA, recommended a shift towards gas usage to reduce the environmental impacts of the Turkish energy generation sector.

Within a similar context, Brizmohun et al. (2015) examined the case of Mauritius, which has rapidly growing electricity demand. They considered the impacts of all electricity generation technologies employed, including coal, oil, sugar-cane bagasse and hydroelectric. Their analyses found that coal and oil are the least sustainable technologies used, and recommended an increase in currently underutilised solar photovoltaic and wind.

The contributions by Atilgan and Azapagic (2015) and Brizmohun et al. (2015) illustrated the importance of recognising the interconnections inherent within current modes of production and consumption. Power generation is fundamental to the modern world, and is responsible for significant environmental impacts in terms of air pollution and climate change. Without advances in this area, firms and organisations, and the general population representing consumers, will find it immeasurably more difficult to further their sustainability in the future.

3.5. Innovation and design approaches for sustainable production and consumption

Innovation and design are critical processes that facilitate change (Leach et al., 2012; Sherwin, 2004). They can be applied to products, processes, systems or organisations and companies (Biondi et al., 2002; Tardy, 2009); the paper within this section are more traditional in their approaches to design and innovation, however they provided important findings for the advancement of sustainable production and consumption.

Following from the focus on energy production in the last section, and holding the same relevance for this introductory article in terms of the potential to contrite to sustainable production and consumption, Theodosiou et al. (2015) integrated environmental management into the optimisation of the design and planning of energy systems. Fossil fuel based energy systems are responsible for many environmental impacts, and as stated earlier in this article, reducing these impacts is critical for achieving climate change mitigation objectives. However, many factors, such as cost, capacity and location must also be included when designing and planning sustainable energy systems. The authors worked to create more pro-environmental outcomes by integrating eco-design principles at the preliminary phase of the conventional design and in the planning phase. Via LCA and multi-criteria analysis, the proposed optimisation model highlighted the ideal available options. The optimisation model was then applied to their case study, the island of Rhodes. Their model helped them to conclude that an almost balanced mix of renewable and non-renewable energy sources, balancing the competing objectives was required for a more sustainable energy system.

3.6. Upscaling and bridging – the role of policy, institutions and methods for connecting societies

All of the contributions and examples outlined above advanced the knowledge and practice of sustainable production and consumption. A key question posed within this SV stream however, concerns how to scale-up and spread such examples more broadly throughout the world.

Governmental policies and regulations are key tools involved in driving and expanding sustainability (Ashford and Hall, 2011). Barrutia et al. (2015) looked at Local Agenda 21, a non-binding voluntary action plan, which was a key outcome of the Earth Summit, held in Rio in 1992. Having been launched over 20 years ago, the authors examined the gap between that vision and how it has been implemented on the ground. A review of journal articles on Local Agenda 21 was conducted. The gap between the ideal and documented implementation of Local Agenda 21 was examined, and explanations for the gaps were sought. Some possible reasons for the gap included limited resources and decision-making powers of local governments, overly hierarchical political systems and a 'top-down' mind-set of many local representatives. However, the authors noted that this approach and Agenda 21, has had a lasting impact on how sustainable development has been implemented. As such, although a mixed picture was found, these approaches could be used to spread sustainability initiatives, especially where lessons from such examples are built upon by a new generation of leaders. This leads us to a key question of this stream, regarding methods for spreading successful examples, and for providing ways to interconnect examples with other relevant contexts. On the one hand, the interconnectedness of the problems leading to current unsustainable production and consumption are significant, interconnectedness is required for further solutions; this interconnectedness, in terms of information and understanding could be used to catalyse successful widespread application of more sustainable approaches.

Another article that addressed upscaling and bridging was written by Thompson et al. (2015), who examined the roles of institutions.

Because institutional changes must be made in order to make some sustainable products and services positive in the business environment, therefore regulations, societal norms or values, must be changed to make them competitive. The central question addressed was how sustainable entrepreneurs have achieved the necessary changes. Through the example of biomass torrefaction in

the Netherlands, the authors found that sustainable entrepreneurs achieved institutional changes through several methods and that collaboration, in the form of trade associations, created feedback effects. This finding was important, as it demonstrated a key facet of a sustainability transition, required for sustainable production and consumption.

Whilst Thompson et al. (2015) examine the perspective of policy and institutions, the paper by Palù et al. (2015) used a method for developing cross-border collaborations as a way to disseminate sustainable production and consumption. The authors examined the context of Small and Medium-sized Enterprises (SMEs), who due to their size and lack of resources were often unable to benefit from research and development units; this in turn limited the SMEs ability to apply environmental innovations. These authors examined the possibilities of technology transfer, across borders (in this case between France and Italy), and between research institutes and SMEs. The authors outlined successful approaches, which included the role of provision of free education. The authors highlighted that such collaborations can provide added values. These authors amplified upon the method for sharing successful examples or approaches to sustainable production and consumption; this is a good example of the benefits of connecting different actors, both in terms of direct sustainability outcomes, but also within wider contexts.

Leigh and Li (2015) investigated methods for enhancing collaboration, in the form of industrial ecology and symbiosis, across supply chains in the UK. Through the development of a framework, the authors used the concepts of industrial ecology and industrial symbiosis to provide a systematic way for incorporating independent concepts such as green purchasing, product stewardship, reverse logistics, recycling and remanufacturing. This approach helped the authors to successfully identify opportunities for supply chain members to enhance their collaboration and achieve enhanced sustainability outcomes.

Whilst several of the contributions in this SV stream are concerned with expanding sustainable production and consumption, and some examine how to enhance collaboration and sharing, there is still a need to fully articulate the requirement to link production with consumption. Several of the previously covered contributions to this SV stream, such as the articles by van Loon et al. (2015) highlighted the roles behavioural aspects play in shifting towards more sustainable futures. This is important to the overall theme of this stream, as we contend that to continue moving towards a sustainable future, inclusion of these perspectives must be increased. Often technological approaches can fail due to behavioural rebound effects, and by following examples such as these, such outcomes may be minimised.

3.7. The need to connect users and producers

In order to limit the impact of behavioural rebound effects, it is essential that users' needs and perceptions are taken into account and integrated into design and innovation decisions at an early stage. This can be seen to serve to bridge the two, as demonstrated in the previous section; however within a different context. Instead of bridging continents or societies, there is a need to bridge the gap between production and consumption in order to integrate user perspectives (Barber, 2003; Stevens, 2010). This perspective was addressed by Morgadinho et al. (2015), through their examination of the perceptions of key stakeholders in the automotive industry. Transportation is a key source of environmental impacts, and requires substantial changes. The authors found that while technological advances will be required, key industry stakeholders also highlighted the need for behavioural changes by users. In addition, the in-depth survey results

revealed that a more holistic approach was required. This demonstrated that many factors must be considered when devising ways to transition to more sustainable futures. In this case, this not only requires inclusion of behavioural and social science perspectives, but also other actors or stakeholders such as users or policymakers for examples. Only through broad and inclusive approaches, can the interconnections inherent within sustainability be accomplished.

Kohtala (2015) analysed the case of distributed production, which is an alternative to mass production, via scale, location and consumer producer relationships. Although its exact environmental implications were unclear, their literature review highlighted that this approach can promote closed loop production, and enhanced product longevity. This requires new producer consumer relationships. The author concluded that distributed production should be addressed as a distinct phenomenon. In terms of this SV stream, however, its key contribution is in terms of highlighting the need for changes in producer–consumer relationships; specifically, these relationships must be bridged and increasingly connected.

In order to take behavioural factors into account, the consumer or user perspective must be integrated within the innovation, design and production processes (Abrás et al., 2004; Kujala, 2003; Liedtke et al., 2012). Through the example of waste management infrastructure in buildings, Ordoñez et al. (2015) illustrated the importance of integrating the user's perspective. In order to reduce waste and to increase resource recovery, better methods of sorting household wastes are required. The researchers investigated the waste-sorting infrastructure in two cases in Sweden. A mismatch was identified between users' needs and the system and infrastructure that existed. This was found to negatively impact performance. The authors concluded that housing companies should install better infrastructure, designed with users' needs in mind.

Daae and Boks (2015) examined the concept of 'user centred design,' and indicated that there are limited insights into the methods available to advance such design approaches for solutions for sustainable behaviours. The authors reviewed user research methods from the literature; where they focussed on factors that affect behaviour, according to the social psychology literature, that could boost sustainability. The results of their review provided an outline of which methods were most suitable; they were then examined through case studies. Value was found in the process of distinguishing between internal factors, such as attitudes or beliefs, versus external factors, such as social norms, and conscious factors, such as intentions, and unconscious factors, such as habits. Through this process the authors interlinked methods with behavioural factors; through a table, this helped them to match suitable methods with specific behavioural factors. Overall this paper provided a central contribution of this stream of the SV; namely, 'user-centred design,' has much potential for bringing production and consumption closer together, and offers a solution for the rebound effect and other behavioural impacts.

Kersten et al. (2015) analysed the need for renovating existing building stock to improve energy efficiency, and hence to reduce environmental impacts. The authors found that there were different ways to engage and motivate residents. Via a participatory approach to design, their exploratory research was designed to investigate how such approaches may help to foster engagement with the beneficiaries of renovation; this was significant, because if motivation to enhance sustainability can be increased by including users in the design process, it is a good approach for the implementation of approaches to support societal sustainability. The authors found that such approaches can provide added value, via 'emerging knowledge transfer', where knowledge is created through interactions. This highlighted the benefits available when

integrating user's perspectives, in this case, residents, into the design and innovation process. By including users in such processes, the potential benefits, often made possible via technological progress, can be fully embraced through behavioural changes.

4. Conclusions

This SV stream provided valuable contributions on sustainable production and consumption. The papers provided answers to many key questions and represented progress in terms of ideas and evidence. These included several examples of specific progress in the application of eco-efficiency concepts, improved waste management or energy saving technologies and practices, as well as advances in product design, measurement and assessment of impact or new approaches, the understanding of organisations, consumers and to a limited degree of how to spread or mainstream good examples.

It was easier to find examples of progress on the production side, than on the consumption side. The authors clarified this reality repeatedly. Many of them increasingly considered the roles of consumers within problems of sustainability and the incorporation of their perspective was found to be very significant. Both within this stream of the SV, and in the wider discourse on sustainability, consumption and the roles of behaviour are increasingly recognised as important considerations for achieving sustainable outcomes. This can also be seen in terms of policies and regulations, traditionally focused on pollution prevention at source, with concepts such as nudging, known from persuasive technology, now being taken up by the mainstream in the UK (Sunstein and Thaler, 2012). Persuasive technologies are those that seek to alter the attitudes or behaviours of users, and so could play an important role in altering consumption activities and patterns.

Similar conclusions can be drawn from the papers in this SV in relation to businesses and organisations; for instance, although CSR has entered mainstream business activities, the next step is ensuring that sustainability is not just an 'add-on' but fully integrated and connected to how businesses operate. Business model approaches and concepts can be conceived as this next step, which may potentially lead to the fundamental redesign of how businesses and organisations operate, for the benefit of societal sustainable production and consumption.

To conclude the introduction to this SV stream, future research objectives and questions that require particular attention to more fully accomplish societal futures, in which production and consumption are more sustainable, are identified.

Due to the multiple objectives that must be satisfied to move towards more sustainable futures, 'win-win-win-win' outcomes, covering economic, environmental, social and time dimensions, are required. These will be based upon better understanding of key drivers and barriers to sustainable production and consumption. For instance, what is the appropriate balancing of drivers, such as economic policies and incentives, more traditional governmental approaches or more novel methods emanating from disciplines such as behavioural economics? And, how well can such methods transcend cultural differences and different sectors? Although there is much research and many examples of successful approaches to sustainability, a key contribution of this SV stream was the clear documentation of the urgent need to develop, test and implement methods and processes that can be used to turn these examples into widely applied success stories. Collaboration and inter-connections are required to successfully implement and to disseminate approaches and methods in many new contexts. The forms, mechanisms, drivers and attitudes that will support effective and widespread implementation are key areas which require

further study and investigation; it is anticipated that such work will further contribute to building bridges for a sustainable future.

One objective, only partially addressed in this SV stream, concerned the identification of mechanisms that allowed successful examples of advances towards sustainable production and consumption to be shared, spread and scaled-up. This is necessary at multiple scales, including where distance, in terms of geography or cultural norms, make such transfers more difficult. The need to bridge in order to share and to expand upon examples of success was evident in numerous contexts. These included the identification and exploration of better methods to transfer knowledge from research to practice, from local examples to national schemes, and in terms of transferring successful regional approaches to other areas. How can best practices be spread among individuals, organisations and nations? And what are the key facilitating factors for successful upscaling and expansion?

To conclude the introduction to this SV stream, future research objectives and questions that are essential in order to realise a future where production and consumption are more sustainable were identified. As this SV stream documented, action only on the production or consumption sides produces limited results, due to phenomena such as rebound effects (Midden et al., 2007). A key question then is, how can consumption behaviours, practices and patterns, and the link to production, distribution and retail, be incorporated into product, service and system designs? New ways of working, collaborating and sharing must be identified, tested, adapted and implemented, which empower consumers, stakeholders and end-users. New ways of working must also provide designers and developers a greater understanding of possible negative impacts of their work via communication or collaboration with consumers, stakeholders and end-users.

As highlighted at the beginning of this paper, it can be concluded that approaches such as responsible research and innovation, which are designed to catalyse the incorporation of key concepts and objectives of sustainability into the research and innovation process, should be at the forefront of present and future transition efforts. The same applies to the concept of 'user-centred design.' When the greater understanding of behaviour and its relationships with consumption patterns is combined with principles such as responsible innovation and user centred design, the gap between production and consumption should be narrowed. This will require closer cooperation among scholars who represent social, engineering and business sciences.

Future research should focus on seeking answers to these questions and topics, while maintaining a commitment to multi-disciplinary methods and the combining of technological and social science perspectives. There is a need to ensure that future work appreciates the interconnections inherent in sustainability, and that solutions build upon these interconnections, as this will provide the basis for future advances for a topic as broad, cross-cutting and important as sustainable production and consumption.

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