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Making the business case for resource recovery

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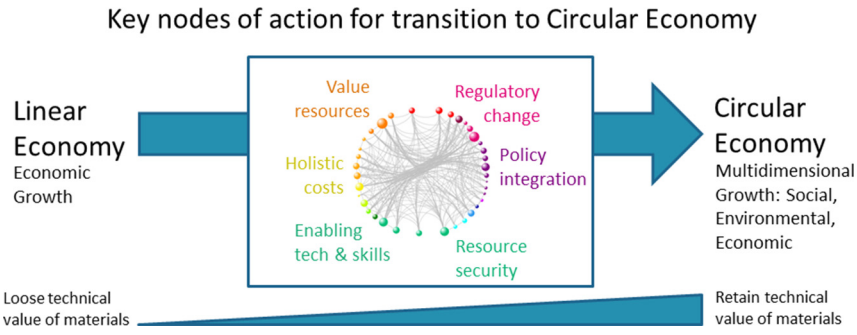
HIGHLIGHTS

- This article outlines how to write business cases for resource recovery.
- Resource recovery experts articulated drivers, barriers and actions.
- Key themes for industry and government business cases were identified.
- Researchers should explain how resource recovery delivers economic and social and environmental growth.

GRAPHICAL ABSTRACT



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ABSTRACT

People altered the biophysical environment upon which they depend through the overexploitation of resources and growing waste generation. Action is urgently needed to return the resource economy within planetary boundaries and safeguard human well-being, by realising an increasingly closed-loop system that maintains values of materials and products within a sustainable circular economy. Innovative technologies and business models must be developed and implemented, requiring convincing "business cases" for industry and government; why should they be interested in adopting circular, resource recovery practices? Despite multi-dimensional challenges facing people and their environment, and the ability of resource recovery to contribute to restoring environment, society and economy, arguments for circular practices are often overly focused on economic aspects. Economic growth is not a panacea and this article supports the preparation of better arguments by presenting expert insights on 37 themes to consider for a resource recovery business case. The most important themes cover 1) Economic, social, environmental and technical value of resources and 2) Regulatory change; focusing business cases on these is likely to deliver positive impacts regarding all identified themes. The article synthesises the old "growth will solve it-" with a new "multi-dimensional challenges and solutions" paradigm, suggesting that resource recovery should support multi-dimensional growth to partly redistribute economic benefits to social and environmental values through the preservation of technical, functional value of materials and products. Writing successful business cases for resource recovery requires inter-disciplinary collaboration, and sustained effort to complete and translate business cases into measurable impacts through changed practices outside academia.

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1. Introduction: the changing values that shape business cases

Resource overexploitation and dissipation of wastes into the environment adversely impact on the Earth's capacity to sustain ecosystem services (Rockström et al., 2009). The planetary boundaries framework put forward environmental limits to guide societies towards a safe operating space where human activities can continue to thrive without destabilising critical Earth system processes. The planetary boundaries of climate change, biosphere integrity, biogeochemical flows, and land systems change have been crossed, and assessment of atmospheric aerosol loading and the impact of novel entities (such as new products) has yet to be definitively assessed (Steffen et al., 2015). A circular economy focusing on waste prevention is a prerequisite for staying within planetary boundaries (Wijkman and Skånberg, 2015).

Ecosystem services are essential to realise and/or maintain a foundation for society (MEA, 2005). While people need to stay below the ecological ceiling of maximum impacts on the environment, the social foundation of well-recognised priorities should also be strengthened – building a "safe *and just* space for humanity" (Raworth, 2017). Prioritised factors for human well-being include food security, income, water and sanitation, health care, education, energy, gender equality, social equity, voice (e.g. political participation, freedom of expression), jobs, and resilience (e.g. the scope and scale of poverty) (Dearing et al., 2014); now covered by the UN Sustainable Development Goals (UN, 2015b).

Current economic models focus on growth i.e. human progress is measured in terms of GDP and/or company profits. This growth, coupling rising industrial activity with increased resource consumption, does not take account of its negative cumulative impact on planetary resources and, consequently, quality of life for people. Recognising multidimensional challenges, from climate change to food security and economic crises, and the inadequacy of existing economic theories to help diverting human society to a more sustainable pathway, Raworth proposed the alternative view of "doughnut economics" (Raworth, 2017).

Doughnut economics emphasise the importance of embedding economic activity within environmental and social boundaries. It reveals the shortcomings of progress with a mono-dimensional focus on economic growth; as if the same economic thinking that caused the widespread sustainability issues will be able to solve them i.e. the "growth will solve it" discourse (Raworth, 2017). Instead, it is necessary to redefine progress and open the scope to a broader set of values including environmental, social and economic factors. This alternative view on multi-dimensional progress needs to be linked to the circular economy to evolve away from measuring success in resource throughput expressed in monetary terms with little regard for future availability of finite resources and the impacts of their extraction, transformation, consumption and disposal. A transition is needed from this open system with unlimited resources to be temporarily exploited towards a new, closed system with a limited set of resources to be permanently conserved; measuring round-put and the nature and quality of resources (Boulding, 1966; Lieder and Rashid, 2016; Iacovidou et al., 2018). As such, it important to add technical, functional value of materials to the value types that make up the well-known triple bottom line (Iacovidou et al., 2017a; Millward-Hopkins et al., 2018).

Material and energy flows need to become part of an increasingly sustainable and circular economy, introduced by the European Union as follows: *"In a circular economy, the value of products and materials is maintained for as long as possible. Waste and resource use are minimised, and when a product reaches the end of its life, it is used again to create further value."* (EU, 2018). Enabling a circular economy depends on concerted efforts from actors throughout society such as producers, consumers, governments, and knowledge- and technology providers (Velenturf and Purnell, 2017). However, there still is a major gap between the obvious issues and practical solutions for global sustainable development and the rationales for individual local actors to create shared environmental, social, technical and economic values (explained in Section 2) (Dyllick and Muff, 2015). This hampers progress towards a sustainable, circular economy. "Business cases" are needed that clearly demonstrate how local actors can benefit from participating in a circular economy: How can resource recovery business cases be articulated for companies and governments? What are the costs and benefits of bringing business practices and government interventions in tune with the circular economy?

This articles aims to outline how the business case for resource recovery can be prepared for industry and government. The objectives are threefold: 1) Identify motivations to adopt a circular economy; 2) Identify challenges encountered when formulating business cases for circular practices and government interventions; and 3) Define actions for academia, industry and government in support of circular economy. Section 2 sets out the background, methods are explained in Section 3, Section 4 presents the results and Sections 5 and 6 complete the article with a discussion and conclusions.

2. Background: from "growth will solve it" to solving multidimensional challenges?

Global sustainability issues are evident and urgent action has been advocated for decades. What has been recommended to government and industry so far, what are the arguments for adopting a circular economy? Here a summary of key points from the extensive academic literature is provided.

2.1. Industry uptake of circular economy practices

The overall picture emanating from the literature is that companies are willing yet lack the knowledge and skills to transform their activities to meet sustainability challenges in a meaningful way. Empirical research into circular economy implementation is relatively scarce, but there is a growing body of evidence suggesting a number of drivers and barriers (summarised in Table 1). Some of these fit into the old "growth will solve it" discourse, such as a focus on short-term financial benefits, and others are more about a new multidimensional approach, such as skills to integrate sustainability with business development.

Dealing with all prime sustainability issues (outlined in Section 1) presents a major challenge for companies (Vermeulen, 2015). Companies need to take a systems-approach that prevents displacement from one issue to another. For example, the move away from fossil-fuel can cause new issues due to depleting natural reserves of metals needed for low-carbon infrastructures (Vidal et al., 2013). Rather than taking a systems perspective, industry strategies have so far been biased towards specific product types and tend to focus on environmental and social issues that are best known, overlooking resource depletion (Vermeulen, 2015). The circular economy offers a framework for companies to engage with global sustainability challenges through the creation of shared value (Genovese et al., 2017). Shared value creation refers to the process in which micro-level values for businesses are combined with creating macro-level values addressing major sustainability issues (Dyllick and Muff, 2015). Despite a growing number of CEOs actively pursuing sustainability and circular practices, the issues are still mounting up (Compact and Accenture, 2014; Dyllick and Muff, 2015). The addressing of global sustainability issues needs to be better integrated with business management.

More practical support is needed to help companies realise the transition towards sustainable, circular practices. Arguably, the first step is recognising challenges outside direct trade relations of a company, and for the company to start addressing the risks and opportunities that sustainability issues may present to them (Dyllick and Muff, 2015). This can reduce risks and costs and simultaneously provide benefits such as increased revenues, brand reputation and competitiveness. However, as Vermeulen (2015) noted, such approaches tend to be

Table 1
Drivers and barriers for companies to adopt circular practices.

Drivers (Dyllick and Muff, 2015; Lieder and Rashid, 2016; Mativenga et al., 2017; Vermeulen, 2015)
Resource scarcity, causing supply risks and making companies vulnerable to supply chain disruptions.
More robust business operations.
Reduced uncertainty about timing, quantity and quality of product returns and material supply.
Limit the mismatch between supply and demand of product returns.
Reduced environmental impacts.
Tax reliefs and policy incentives.
Greater staff commitment and productivity.
Customer loyalty.
Competition, for example competitors adopting circular practices that improve value propositions of products/services.
Reduced costs or increased profits.
Pressure from customers and societal groups for sustainable resource use and business operations; responding to such pressures prevents potential reputational damage.
Barriers (Ghisellini et al., 2016; Kraaijenhagen et al., 2016; Linder and Williander, 2017; Ritzéna and Sandström, 2017; Velenturf, 2016; Vermeulen, 2015)
Financial, such as lack of business cases showing potential revenues and focus on short-term returns on investment.
Markets, such as customer demand being limited to niche markets.
Structural barriers external to companies such as renegotiating supply chain responsibilities, dependencies (more dependency makes change more difficult) and integrating perspectives of supply chain partners, and ability to change practices of suppliers.
Structural within companies, such as balancing top-down direction-giving and allowing bottom-up experimenting, and integrating different departments.
Attitudinal, such as understanding of circular economy, risk aversion and preference for incremental change, missing the strategic relevance of sustainable development and necessary radical changes to business models, and ability to integrate perspectives on sustainability and business development.
Technological, such as quality of recycled materials and logistics of taking back products.
Skills shortage to manage the radical innovations needed to transition towards a sustainable, circular economy, for which knowledge often needs to be sourced from outside the organisation.
Collaborative, successful cases involved actors from across society and creation of suitable collaboration and exchange patterns.

patchy and are unlikely to address sustainability issues in a sufficiently coherent and significant manner. Companies are still part of the old "growth will solve it" reasoning.

A step up would be to integrate the delivery of environmental and social values into the core business operations through more purposeful stakeholder conversations and a programme of work to address specific issues (Dyllick and Muff, 2015). Companies can push even further by redesigning their business models to deliver products and services that not only provide values to their direct customers but also for society and environment i.e. creating shared value (Dyllick and Muff, 2015). In this way, the costs of dealing with sustainability issues can be included in the price of products and services (Vermeulen, 2015). A general shift from selling products to selling services is envisaged, thereby increasing performance and product lifetimes and reducing the use of materials and energy as well as detrimental environmental implications; a new economic structure of product loops consisting of reuse, repair, remanufacturing and recycling can be created (Stahel and Mullvey, 1981). The viability of truly sustainable business models that contribute to the common good depends on changing economic structures and government support (Genovese et al., 2017); companies will need to be active in voicing the required changes (Dyllick and Muff, 2015).

There is consensus that governments cannot rely on self-regulation alone given the speed of change that is required to address the scale of environmental challenges and social inequity (e.g., Ghisellini et al., 2016; Vermeulen, 2015). Without government support, companies may remain stuck in the old "growth will solve it" narrative, working from the narrow basis of cost reductions offered by increased recycling and economic returns on investment to motivate themselves and investors (Mativenga et al., 2017) rather than addressing the broad set of multidimensional challenges in an integrated manner.

2.2. Recommended government support for circular economy

Public policy needs to be linked to industry initiatives (Costa et al., 2010; Genovese et al., 2017; Vermeulen, 2015). Given the impacts of resource use and pollution on the environment and people, and that acting upon those issues is crucial for meeting international agreements on e.g. climate change and sustainable development goals, governments are obliged to act (UN, 2015a; UN, 2015b). Moreover, governments have a "social contract" to create the best conditions for everyone within the borders of their country, and offloading environmental, social and economic challenges to companies could be seen as a breach of contract. This has led to court cases against the state in, for example, the Netherlands and the UK (BBC, 2018; Urgenda, 2018).

Benefits of greater circularity that appeal to governments pertain to resource security, greater resource efficiency, carbon reductions, pollution prevention, economic growth, and jobs (Genovese et al., 2017; Lieder and Rashid, 2016; Wijkman and Skånberg, 2015). While these are laudable benefits to deliver for society, they are abstract and must be better connected to the interests and concerns of those in power if they are to act upon them (Velenturf et al., 2018). A multitude of government interventions has been recommended to support a sustainable, circular economy (summarised in Table 2). However, understanding

Table 2
Government interventions to enable a sustainable circular economy.

Scope	Details
Planetary boundaries	Design policies to monitor planetary boundaries and pick up early warning signs to leave sufficient response time (Steffen et al., 2015). Combine with measures regarding immediate demands for resources such as water, food and energy (Steffen et al., 2015; UN, 2015b). Adopt resource efficiency measures as key instrument of climate policy (Peake, 2018; Wijkman and Skånberg, 2015).
Resource efficiency	Set resource efficiency targets, especially for scarce materials and materials whose extraction causes severe environmental implications (Wijkman and Skånberg, 2015). Create, coordinate and evaluate a circular economy focusing on product groups generating most impacts; focus on all major sustainability issues and look both upstream at extractive and manufacturing industries and downstream at end-of-use management of products, in which resource use and waste management are transparently governed, enhance shared value creation, and promote collaboration for eco-design (Vermeulen, 2015).
Economic change	Integrate circular economy into national competitiveness strategies (Wijkman and Skånberg, 2015). Promote business models focusing on provision of function rather than selling of resources (Wijkman and Skånberg, 2015). Use procurement processes to collaborate closely with companies to give them the opportunity to develop sustainable business models (Witjes and Lozano, 2016). Update business support guidelines that emphasise benefits such as reduced material costs and more profit (EU, 2016) to reflect the multi-dimensional benefits.
Procurement	Support sustainable development through procurement (UNEP, 2014; Ekins et al., 2011; Stahel, 2016; Walport and Boyd, 2017).
Tax	Use tax instruments effectively, for example by lowering taxes on labour and products made from secondary resources, and increasing tax on the use of non-renewable resources (Wijkman and Skånberg, 2015).
Waste prevention	Support waste prevention through existing- and new legislation such as a Waste Prevention Act (Lieder and Rashid, 2016; Velenturf et al., 2018). Strengthen extended producer responsibility legislation to minimise wastes and increase recycling rates.
Innovation	Support innovation by investing in research and dissemination; organisational, social, and technological innovation; and multi-stakeholder collaborations (EU, 2018).

which (and how) specific interventions lead to success is still limited (Lehtoranta et al., 2011; Madsen et al., 2015; Velenturf, 2017).

It is important that governments provide long-term clarity about the direction of travel. Nevertheless, the realisation of a circular economy strongly depends on local context (Costa and Ferrão, 2010; Jensen et al., 2011; Taddeo et al., 2017). Aspects such as regional industrial diversity, business drivers and barriers, the quality and volumes of secondary resources available, existing ownership models and current recycling and disposal activities all need to be considered when planning and implementing circular practices (Jensen, 2016; Mativenga et al., 2017). Understanding the intricate relations between actions in support of a circular economy and the characteristics of specific localities is an area of on-going research (Taddeo et al., 2017).

2.3. Are we getting there?

Despite the long-standing and regularly reconfirmed acceptance that a transition to "a circular and fair global economy" is critically important (UN, 2015b; Vermeulen, 2015), growth, resource exploitation and waste production are still accelerating (UNEP, 2016). Decoupling of economic growth from resource use is happening; however, the benefits are offset through accelerating global growth and the rebound effect (Bithas and Kalimeris, 2018; Druckman et al., 2011; Wijkman and Skånberg, 2015). Countries like the UK celebrate achieving greater resource efficiency but in reality western countries tend to outsource manufacturing including its associated negative environmental and social consequences (Barrett et al., 2018).

Implementing a sustainable and circular economy is still in its early stages (Ghisellini et al., 2016; Haas et al., 2015; Lieder and Rashid, 2016; Ritzéna and Sandström, 2017). Academic research has fallen short in articulating business solutions that address multi-dimensional economic, social and environmental challenges (Dyllick and Muff, 2015). Governance for planetary boundaries is still faced with "severe implementation gaps" (Steffen et al., 2015). Practical guidance is underdeveloped for the collaborative approaches to engage all necessary stakeholders when implementing a circular economy (Kraaijenhagen et al., 2016; Lieder and Rashid, 2016; Velenturf and Purnell, 2017). Academics have analysed sustainability issues into great detail but the literature is less well developed with regard to practical solutions and articulating how they can be implemented. The remainder of this article strives to contribute to covering this knowledge gap by investigating how practically-relevant, pragmatic business cases for resource recovery, as part of an emerging circular economy, can be formulated.

3. Materials and methods

3.1. Data collection

Data were collected at the Resource Recovery from Waste (RRfW) annual conference on "Making the Business Case for Resource Recovery" in November 2017 in Leeds (UK). RRfW is an academic research partnership bringing together universities, governmental bodies, companies and third party organisations (Resource Recovery from Waste, 2018). The programme supports a transition towards a circular economy that contributes to a resilient and healthy environment, creates benefits for people such as reduced air pollution and high-quality jobs, and clean growth through greater resource productivity.

The conference attracted 68 experts from a diverse background yet all working on circular economy (Fig. 1) and mostly from the UK (93%); 18% were professors, 9% directors and 16% other senior management. The event opened with a plenary session discussing overarching drivers and challenges to formulate successful business cases for resource recovery; followed by parallel sessions on core subjects within RRfW, including bioeconomy, landfill mining, and sustainability assessments; and concluded with a plenary session on policy and regulatory change, taking due regard for the UK leaving the EU. The conference

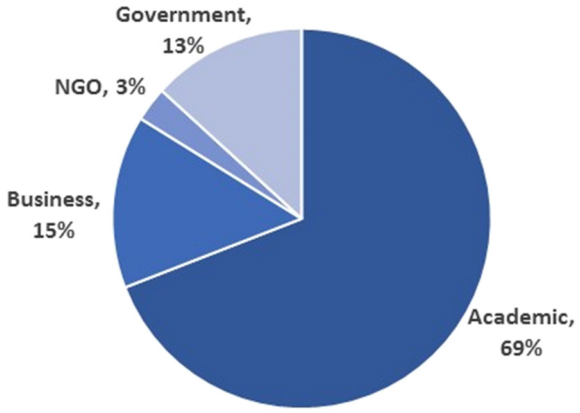

Fig. 1. Delegates that contributed to the data at the Resource Recovery from Waste annual conference on "Making the Business Case for Resource Recovery".

programme, presentations and detailed proceedings have been published on the RRfW website (Resource Recovery from Waste, 2017) and the conference proceedings are included in Supplementary information A.

Delegates were asked to capture data on business cases throughout the conference on 1) Motivations- and 2) Challenges for industry or government adopting resource recovery, and 3) Actions in support of resource recovery. Notes were taken on post-its and could include literal messages heard in presentations and discussions or original ideas from the delegates. Each session also had dedicated scribes to provide additional data capture capacity.

During the parallel sessions, delegates were asked to organise the motivations and challenges into environmental, social, economic and technical domains (categories based on Iacovidou et al., 2017a; Millward-Hopkins et al., 2018). Further discussions were facilitated to identify additional motivations or challenges, and to assign actions to different actors (government, industry, academic, other). The session scribes took notes of suggested actions. The parallel sessions were followed by a brief plenary feedback discussion to share the most important findings and give space for questions and further comments.

3.2. Data analysis

Data were prepared by literal transcription (Mason, 2002). Post-it data were entered into Excel. Post-its were given a unique identification number to enable tracking back to the data source during the analysis. In addition, the conference session where data were collected, type (motivation, challenge or action), and literal transcription of comment were all recorded as part of the data set.

The notes from all scribes were combined into a Word document. The presentations were revisited to clarify the notes where necessary (all presentations have been shared on the conference webpage Resource Recovery from Waste, 2017). The notes were coded in the same way as the post-it data, identifying motivations, challenges and actions. Coded fragments were transferred into the Excel file with the post-it data to enable coherent analysis of all data. About 500 entries from post-its and coded fragments were collected.

All entries were assigned types (Motivation, Challenge, Action) and subtypes (filling in where there were gaps in the data). Following the structure set-out in the data collection; subtypes for challenges and motivations were environmental, social, economic and technical, and a general category was added. Subtypes for actions were industry, government, academia and other. Initial themes were added through open coding (Mason, 2002). Data were checked for double entries. For example, when delegates literally noted the same information in the same session, then the assumption that they were the same suggestion

was considered reasonable and the entries were merged. The analysis was purely qualitative, no additional weight was given to suggestions that were made multiple times. Instead, all unique suggestions were captured for analysis.

After merging duplicate entries, the data were critically re-examined. The coding into themes was completed and an initial coding tree was drawn. The data were then split into 1) Challenges and motivations and 2) Actions, and analysed further separately. The first dataset was consolidated by sorting the data by theme allowing coherency checks of the coding. Detailed interpretations summarising the main points of each theme were added and included in Supplementary information B.

Relations between themes were analysed. Relations were identified when a) Literal references were made i.e. the connecting theme was literally mentioned, or b) When connections were implied and could be clearly formulated based on the information literally conveyed in the data. An undirected network graph of the relations was produced with NodeXL (2016). Network theories suggest that the more connected or central a node is within a network, the more powerful it may be (Scott, 2000). Based on this, it was reasoned that the more connected a theme is, the more likely it is to impact on the rest of the network. Highly connected themes were interpreted as key intervention points where actions could arguably have greater impact.

Actions were summarised and listed by type of actor. They were then related to the themes that were identified in the analysis of Motivations and Challenges.

To conclude, a rigorous, systematic qualitative study was carried out. Trustworthiness was assured through the four research quality indicators (Lincoln and Guba, 1985) of credibility (through co-production of the results with the conference delegates), transferability (reflection upon existing literature from an international context), dependability (through transparency and keeping detailed notes of the research process) and confirmability (accepting that complete objectivity is unlikely and offering readers opportunity to check and reach their own conclusions with the materials provided in Supplementary information A and B).

4. Results: themes and actions for the business case

This section first presents the main themes or "ingredients" of the business case for resource recovery (Section 4.1). Section 4.2 identifies key intervention points where most impact can be made. Section 4.3 concludes the results with actions, including further research suggestions, to promote resource recovery in a circular economy.

4.1. Themes for the business case for resource recovery

In total 37 themes were identified across the five subtypes of challenges and motivations (social, technical, environmental, economic and general). Table 3 provides an overview and Supplementary information B contains full detailed descriptions of data coded within each theme. Overall there are as many motivating as challenging themes (12) but within the technical and economic subtype there are relatively many motivators.

The themes indicate various aspects that are focused on cost savings and growth. **Lower monetary costs** (bold text in the results corresponds with theme titles in Table 3) says that resource recovery should deliver cost savings and improve competitiveness. Low-cost recovery technologies developed within RRfW make the mining of metals from "anthropogenic ores" an affordable pollution control measure (**Recovery costs**). Both cost-related themes were considered to motivate resource recovery (Table 3).

Currently recovered secondary materials have a relatively low monetary value compared to primary materials, but even so resource recovery and circular economy are growing in the UK and offer opportunities for low-carbon business development. Increased resource efficiency delivers monetary benefits to companies. Global resource prices are expected to increase and hence it is expected that the best performing economies in 10–20 years will be those that become the most resource efficient. **Growth** opportunities were perceived as drivers for resource recovery (Table 3). **Capitalism** holds a warning to move away from maximising financial returns only, because from a global- and whole-system perspective this approach is not progressing people towards sustainability; it is constraining viable resource recovery business cases (Table 3). As indicated in Section 2, the UK has offshored environmental impacts from manufacturing (raw material consumption, carbon emissions), simultaneously domestic waste generation and associated issues are rising (**Waste and resource paradox**). This set-up, with less control over resources flowing into the country and growing waste challenges, constrains resource recovery (Table 3).

The motivating **Holistic** theme suggests that we need to adopt a whole-systems approach to reduce primary resource use. Resources must be valued throughout their lifetime, taking into account their economic value but also costs associated with environmental and social impacts; **Internalising externalities** suggests pricing these costs into the production-consumption system but it is a challenge (Table 3). **Value resource** proposes to change the value perception of primary and secondary resources even further, including economic, social and environmental as well as the technical, functional value of materials and products. A holistic systems-level understanding of multi-dimensional value dynamics underpins supply chain design to minimise value destruction and maximise value at end-of-use. Similarly, the **Holistic costs** of not managing wastes appropriately, for example dumping or open-air burning, exceed waste management costs by a factor 5-10. Inappropriate waste management and lack of infrastructure leads to land, water, and air **Pollution**, contributes to climate change, poses environmental and human health threats, and results in economic costs through lost productivity – all of which are avoidable through waste management. Assessing and acting upon multi-dimensional costs and benefits is challenging yet is an important driver too (Table 3, discussed further in Section 4.2).

Resource recovery offers business opportunities, prevents pollution and contributes to resource security. For example, the UK depends on importing critical materials for low-carbon infrastructure. These materials can be recovered from anthropogenic ores (e.g. mine tailings, industrial landfills) and electrical wastes, thereby contributing to domestic resource- and energy security and creating business opportunities; moreover, the decreasing demand for primary materials reduces conflict in mining areas abroad. **Resource security** offers important motivations for resource recovery. Another example is offered by recovering energy from organic wastes and returning the residues to agriculture as low-carbon soil improvers, thereby restoring **Ecosystem services** offered by healthier soils and contributing to **Food security**. Resource recovery can have a positive impact on **Land value**, recovery of metals from anthropogenic ores decontaminates land and enables alternative land-designation, although at a trade-off for the current landscape values associated with the mining heritage, while in the case of returning nutrients to agriculture the land-use can be sustained into the future.

These resource recovery solutions address multiple sustainability challenges and profess to be better than linear take-make-waste practices. This needs to be assessed with environmental, social, technical and economic indicators from a whole-system perspective; posing the challenge of achieving **Sustainable circularity**. Adopting increasingly circular practices is part of **Wider transitions** focused on minimising value destruction and towards a more decentralised, functional, bio-based, sharing and self-producing economy in which **Collaboration** plays a key role. Sustainability issues have many owners that need to be involved in collaborative solutions, from government strategy to infrastructure investment, business models and commercialisation, and sharing of expertise and evidence regarding the costs and benefits of circular economy.

Table 3
Themes suggested as part of business cases for resource recovery. Detailed descriptions reflecting the full range of data included in each theme are provided in Supplementary information B. Legend: Subtype: EC = economic; SOC = social; ENV = environmental; TECH = technical; GEN = general. Challenge/motivation: Red = challenge; Orange = challenge and motivation; Green = motivation. Connections = number of relations to other themes.

Theme	Type	Challenge/motivation	Connections
Business models	EC		17
Capitalism	SOC EC		9
Carbon emissions	ENV EC		18
Change behaviour - consumers	SOC		10
Change behaviour - producers	SOC GEN EC		18
Circular economy infrastructure	SOC TECH EC		17
Collaboration	SOC		15
Commercialisation	TECH EC		17
Data: waste composition	GEN		15
Ecosystem services: organic waste	TECH ENV		13
Enabling technology and skills	TECH		22
Food security	SOC		8
Governance capacity	SOC		12
Growth	EC		16
Holistic	GEN		17
Holistic costs	SOC ENV EC		20
Human health	SOC ENV		8
Industrial diversity	TECH EC		15
Internalising externalities	SOC EC		15
International agreements	SOC		14
Investment	EC		12
Jobs	SOC		5
Land values	SOC ENV EC		6
Lower monetary costs	EC		9
New products	TECH		12
Policy integration	SOC		20
Pollution	ENV		12
Recovery costs	EC		8
Regulatory change	SOC EC		25
Reputational risk	SOC		7
Resource quality	TECH		10
Resource security	TECH EC		22
Standards	SOC TECH		9
Sustainable circularity	GEN		15
Value resource	GEN EC		26
Waste and resource paradox	GEN EC		15
Wider transitions	GEN EC		13

The evidence base is a particular concern in promoting resource recovery. Data gaps constrain business cases and government measures to promote resource efficiency. A combination of digital technologies, standards, legal obligations and reporting requirements can aid the collection of compatible data on flows of quantities and multi-dimensional values of resources and wastes through the economy; supporting policies and regulations are essential to overcome the challenge of **Data on waste composition** (Table 3). Generally, regulation and policy uncertainty pose constraints for resource recovery. The regulatory culture and short-termism need to change. Voluntary measures need to be complemented by mandatory and economic measures including taxation in for example embodied carbon contents, strengthening 'polluter pays' principles, regulatory harmonisation and additional regulation to enable recovery from diverse waste streams including anthropogenic ores and bioenergy residues, broaden the scope of waste management targets to include waste minimisation, reuse etc., and take measures to maintain access to the EU market (**Regulatory change**). Government action in the UK on circular economy, sustainable development and climate change is guided by **International agreements** (global, EU). **Carbon emission** targets are driving resource efficiency (Table 3), and **Policy integration** should be promoted across the domains of waste management, climate change, infrastructure, and resource productivity. All these changes require **Governance capacity** and this is a challenge (Table 3) in the UK with a shortage of funding and people to integrate circular economy into policy, translate research into practice, and implement legislation. Hence the government searches for cost-effective interventions.

Government can contribute to realising a circular economy through its **Investment** profile. In the UK a challenging £5–£25bn public investment is needed for business model- and technological innovation. Arguably, the UK's resource efficiency track record can drive government investment. However, the lack of compatible data on required waste management capacity holds back investment into sufficiently diverse circular economy infrastructure. More diverse resilient **Circular economy infrastructure** is needed that meets capacity demands at relevant geographic scales. Ambitious government waste management targets would drive investment higher up the waste hierarchy than energy-from-waste and for all types of waste including those containing (near) critical materials. Circular economy infrastructure must be integrated into the wider industrial structure to ensure there are markets for recovered materials. The industrial strategy should strive to develop complementary **Industrial diversity** in manufacturing sectors that is present in the right locations demanding recycled materials, embedded in a resilient industrial system designed for circularity that can be responsive to resource dynamics.

The demand for industrial diversity is underlined by the theme **Business models**, since closed- or cascading loops of material flows connect sectors through new supply chain collaborations and collective value propositions around cost reductions/increased economic value, better product design and changes in ownership models. **New products** are being developed from wastes, offering business opportunities but also challenges such as **Resource quality** (Table 3). For companies recovering resources it is challenging to supply a steady quality of recyclate, especially in international markets. One solution is reporting, and

Standards can support such measures to improve information about recycled contents, thereby reducing risk, enabling growth and export, and increasing trust and consumer confidence in quality of recyclate compared to virgin material. Producers consider **Reputational risk** (or opportunity) of using secondary resources. To **Change behaviour of consumers**, education and information provision about material usage are considered vital, together with better collection services that make sustainable behaviours easier. The most impact, however, could be achieved by a net-reduction of consumption. Business model innovation and **Changing behaviour of producers** are necessary, but capacity gaps (money, time, resources) pose challenges to change. Some entrepreneurs are personally driven to radically change and innovations within companies are sometimes delivered through internal missions. Externally, Life Cycle Assessment (LCA) can be used to drive circularity. However, more than anything, the **Commercialisation** of new products and resource recovery processes depend on economic feasibility pertaining to profitability and/or the costs being the same or less than existing solutions. There is demand for scalable technologies. **Skills and technologies** developed in the UK drive resource recovery (Table 3) and can be exported, offering growth opportunities and creating **Jobs** domestically and abroad.

4.2. Key intervention points

Researchers can use the themes listed in Table 3 as "ingredients" for a business case for resource recovery, to help formulate clear arguments in favour of new technologies, approaches and products. Using the full list would amount to a lengthy argument though, and this section uses network analysis to suggest a smaller subset of key themes.

Fig. 2 is a network graph of the relations between the themes. Analysis of these relations identified that the most connected themes are:

1. Value resource (26)
2. Regulatory change (25)
3. Enabling technologies and skills (22)
4. Resource security (22)
5. Holistic costs (20)
6. Policy integration (20)

All of these themes are partly economic, and they are all (partly) motivations. Since these themes are the most connected, directing change through these key intervention points may have the most impact on other parts of the network if we leverage the motivating potential.

It should be easier to make the business case for actions that are directed via the most connected themes. Actions come at a cost and may deliver benefits, and for changes directed via key themes there may be cascading benefits in other themes too. For example, in the case of changing how we value resources, additional benefits can be achieved from business model innovation, low-carbon growth, and internalising externalities. However, how we value resources is likely to depend on changes in policy and regulation. Starting points for government interventions in the supply chain can make a crucial difference; if environmental and social costs included first in secondary resources, then these will become even less competitive compared to primary resources and hence producers may turn to accelerate natural resource extraction unless government makes further costly interventions to incentivise usage of secondary materials. Conversely, if such intervention was first directed at primary materials, then these would become relatively expensive and hence this would be a more efficient use of capacity to steer towards greater circularity.

Conversely, little impact may be derived from directing actions through the least connected themes. These are:

1. Jobs (5)
2. Land Values (6)
3. Reputational risk (7)
4. Food security (8)
5. Human health (8)
6. Recovery costs (8)

These themes are social or part social (except Recovery costs) and they are all (partly) motivations. This analysis does not mean that the least connected themes are not important, but they are perhaps not the most influential place to intervene.

The complete matrix data used to produce Fig. 2 has been included in Supplementary information C, together with network graphs showing the highlighted connections of the most and least connected themes to gain a greater insight into the data.

4.3. Actions for making the business case

Which actions did the expert audience at the RRfW conference recommend? The results are organised by intervention point (Table 4). Most actions pertain to **Policy integration**, **Regulatory change** and **Governance capacity**. These themes are well-connected (Fig. 2) and, if actions are taken, should result in cascading impacts on other themes. Actions for academic researchers include providing knowledge and evidence, making the business case for resource recovery to government, and keeping government and industry to account regarding progress towards a circular economy. Government itself must provide long-term stability, govern resources and wastes from the perspective of economic policy and not just environmental issues, and enable and promote recycling and recovery through various regulatory changes (additional actions in Supplementary information B under Regulatory change).

The remaining actions are more dispersed and in many cases less specific. Industry should consider **Resource security** and while this is a key ingredient for the resource recovery business case (Fig. 2), more specific actions need to be determined to capitalise on this driver. Conversely, actions regarding **Investment**, **Circular economy infrastructure** and **Industrial diversity** were more specific. Government needs to invest strategically into circular economy infrastructure and other projects while industry should develop refurbishing and remanufacturing activities. On the **Business model** and **Change behaviour – producers** themes, general actions were suggested for industry such as changing business models and using LCA to drive supply chain change. **Data on waste composition** is an important barrier to change (Fig. 2) and government can resolve this issue by launching a new Office for Resource Stewardship that provides the necessary information on primary and secondary resource flows to support decision-making and investment in circular economy. Closing material flow loops can be aided by **Standards**, requiring a broad range of actors in its development, but since standards are not central in the network (Fig. 2) they should perhaps not be prioritised when driving change. Academia can further contribute through educating the general public, who in their turn can inflict change upon industry and government. Nevertheless, the results suggest that **Changing behaviour – consumers** is not the most efficient way to promote circular economy.

In addition to the actions in Table 2, conference delegates identified numerous further research activities to develop **Enabling technologies and skills** (a key component of the business case, see Fig. 2) and **New products**. Generally, academia should continue with cross-disciplinary research through international collaborations and focus on:

1. Designing wastes out of the economy through prevention, improved durability and recyclability of products.
2. Supply chain integration to connect waste producers and users.
3. Recycling and recovery technologies for textiles, metals (faster acting leaching technologies), plastics (methods for separation, recognition and recycling), construction wastes (recovery processes for bulk aggregates).
4. Bulk formulation process for mixing ash and digestate (related to RRfW AVAnD project).

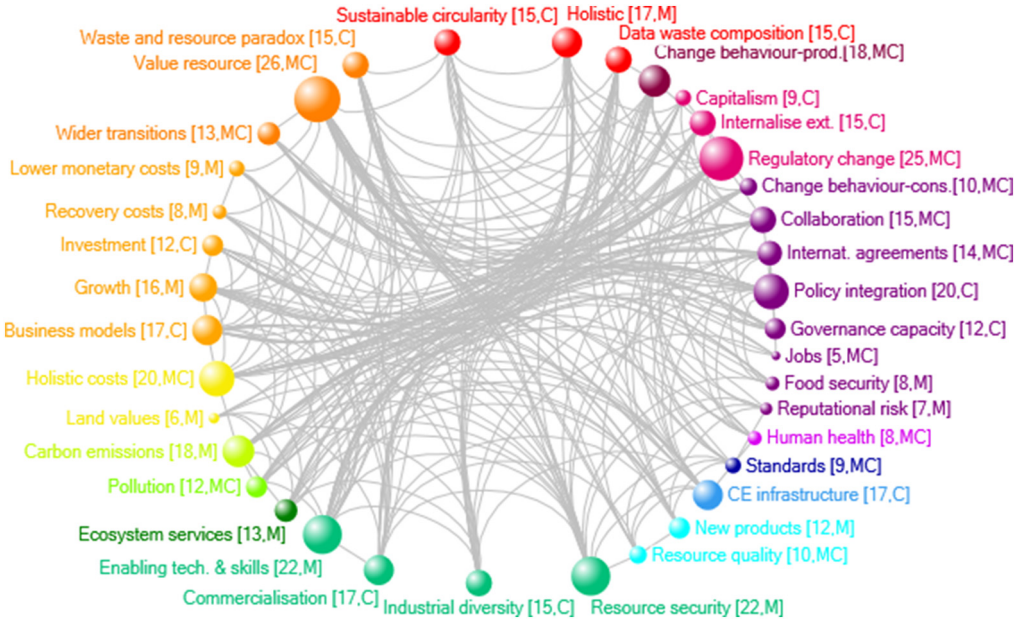

Fig. 2. Relations between themes of the business case for resource recovery. Legend: Node sizes are relative to the number of connections. Red = general; Purple = social; Aqua = technical; Light green = environmental; Light orange = economic; and transition colours thereof indicate combinations of any of these types. C = challenge; MC = motivation and challenge; M = motivation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

5. Energy solutions: invent, scale up and industrialise processes using CO_2, more affordable low-carbon energy solutions; upgrade pyrolysis oil to enable wider use.

Overall, relatively few actions and further research ideas (about 50) were suggested when compared to the motivations and challenges (about 300 unique entries). No actions were proposed to act upon the key business case ingredients **Value resource** and **Holistic costs** although actions are implied in the description in Supplementary information B. Government needs to make primary materials more expensive than secondary materials via taxes or incentives. International agreements, such as on climate change and sustainable development, can support holistic costing of resources. Industry needs to innovate business models and especially adopt more product-service systems. In general, products and supply chains must be redesigned to prevent waste and enable refurbishing, recovery, etc.

Reflecting upon the data collection, conference delegates easily identified motivations and challenges for business cases for resource recovery and circularity. Delegates had a readily available understanding of the problems at hand. However, identifying solutions to capitalise on motivating factors available to us and to overcome the challenges on the way towards a sustainable circular economy was a difficult task and this is reflected in the results discussed herein. This suggests that the emphasis of academic efforts need to shift from problem description towards more solution oriented research.

5. Discussion: synthesising the old and new paradigm

5.1. Balancing growth and sustainability

The key themes presented in the results contain aspects that fit into the old "growth will solve it" and the new "multi-dimensional challenges need multi-dimensional solutions" discourses. Researchers that have developed innovative technologies and approaches for resource recovery need to find a middle-ground linking the old and new discourse when making the business case for the uptake of their research outcomes by government, companies and others.

Like it or not, the current dominating paradigm is focused on economic growth. When interacting with companies and government, there is no escape from this reality. Researchers will have to respond to financial concerns and opportunities associated with resource recovery. For example, for commercialisation it is important to address the monetary costs of resource recovery and the value of recovered materials. Arguably it is logical to speak about business opportunities and reinvesting cost savings from increased resource efficiency into business growth. After all, it is important that businesses operating in a circular fashion out-compete those operating within the purely linear take-make-waste frame.

However, as reasoned by Defra's Chief Scientist (Boyd, 2017), a 100% circular economy is impossible due to laws of thermodynamics. Materials cannot be circulated indefinitely within the technosphere, there are likely losses of volume and quality each time materials are recirculated into a new production-consumption cycle. It is likely that primary resources must be added when manufacturing new products. Indeed, only 12% of material inputs into the global economy are recyclates (Krausmann et al., 2017). Depending on the complex interactions between cost savings through resource recovery, proportion of savings reinvested into business growth, use of recycled content in the next production-consumption cycle, and various other factors; even an increasingly circular production-consumption system could still contribute to accelerating natural resource extraction and associated negative environmental and social implications.

In other words, if economic savings result in economic reinvestment into natural resource extraction, then a systems-level rebound effect is likely that undermines environmental and social restoration. A redistribution of value from economic to the social and environmental domains through maintaining technical value is needed. When building resource recovery business cases we need to ask: What is the economic *and social and environmental* growth that can be achieved through resource recovery? Where should we invest the economic wins to enable the complete supply chain to transition from being an environmental- and social drain towards net-positive contributors?

It is also important to consider the limitations of resource recovery contributing to solutions for global sustainability issues. Population growth and economic development contributed to increasing natural

Table 4
Actions for academia, government and industry to make the business case for resource recovery.

Actor	Action(s)
Themes: governance capacity, regulatory change and policy integration	
Academia	Keep industry and government to account and challenge them, making sure their actions are robust and that policy and regulation is effective. Transfer knowledge about circular economy to government. Share concise written business case for resource recovery with key government leaders. Show social, environmental and economic benefits of circular economy to government, aiming to attract public investment. Provide evidence to government about the safety of using resource recovery technologies such as metal recovery from old mines and industrial landfills.
Government	Give (bio)renewables a competitive advantage over non-renewable resources through financial measures. Shift the regulatory focus from primarily public health and environmental protection to include resource stewardship for productivity and security. Rethink policies when leaving the EU and adopt a long-term vision for systemic change that maximises values from resources and minimises impacts of products at end-of-life. Outline a long-term policy agenda that provides stability for at least 10 years. Align policies with the available funding and enforcement capacity. Set regulatory targets to increase recycling in general and reduce food waste in particular. Price externalities into product costs via carbon pricing in energy- and resource management. Adopt regulations that enable waste reprocessing in-situ.
Theme: data waste composition	
Government	Open an office for resource stewardship that will monitor environmental performance and collects data on primary and secondary material flows to support decision-making and investment.
Theme: standards	
Academia Government Industry	Support the development of standards.
Theme: change behaviour consumers	
Academia	Educate the general public about circular economy to indirectly impact on actions of actors in power to enact change.
Themes: business models and change behaviour producers	
Industry	Use LCA in decision-making to take environmental and possibly socio-economic aspects into consideration. Make business models more sustainable and circular through innovation.
Themes: investment, circular economy infrastructure and Industrial diversity	
Government	Invest in large-scale strategic projects to stimulate circular economy.
Industry	Develop business activities in refurbishing and remanufacturing.
Theme: resource security	
Industry	Consider secondary resource availability, primary resource supply risks, and ways to close material flow loops when making the business case.

resource extraction 23-fold in the period 1900–2010; half of these resources are stocked for a long time within the technosphere in the form of buildings, infrastructures etc. (Krausmann et al., 2017). Extraction is forecasted to grow: for example, energy demands will double between 2014 and 2040 resulting in a rise of extracted oil (12%), natural gas (49%) and coal (5%), and demand for steel and copper will grow 120% between 2010 and 2040 (UN, 2018). The shift towards renewable energy will escalate demand for both base and (near) critical metals (Vidal et al., 2013). Even if recycling of all materials is maximised, then natural resource exploitation still has to grow significantly to meet demand. It is crucial that other innovations, aside from resource recovery, are pursued (Haas et al., 2015) – as indicated by the "Wider transitions" theme. It is necessary to limit throughput with alternative business models that increase the intensity of product use (e.g. collaborative consumption) and extend product lifetime (e.g. product-service systems, repair) (Bocken et al., 2014; Lieder and Rashid, 2016). Simultaneously, it is paramount to drive cultural change to become less materialistic by developing an alternative lifestyle to which people can aspire (Raworth, 2017).

5.2. Best practice in writing business cases

When discussing the wider implications of new technologies and approaches, researchers should "rebrand" economic growth into multi-dimensional growth and subsequently outline the economic, social and environmental costs and benefits associated with the recovery of technical, functional value of materials. The results indicate that this is the type of argument that will deliver the most cascading effects also touching upon the other aspects of the business case (Table 3, Fig. 2). Moreover, the lack of suggested actions to consider multiple types of value of resources, show how important it is that academics explain this further in their publications.

Practitioners in government and industry have developed set methods to prepare business cases for changing existing operations, often realised through project management. Academic researchers can increase their impact by connecting their business case arguments to existing practices for implementing change in government and industry. The APM Body of Knowledge proposes that a typical business case should cover six areas (APM, 2012):

1. Strategic case for why action is needed
2. Appraisal of available options, including "do nothing" scenario
3. Expected benefits and dis-benefits
4. Commercial aspects such as costs and investment appraisal
5. Risks and their impact on the anticipated outcome
6. Project delivery timescales and anticipated benefits

The PRINCE2 methodology recommends similar elements, in addition to an investment appraisal that compares project costs to the financial value of the benefits over a time period (Office of Government Commerce, 2005). Intangible benefits are expressed in more tangible, monetary terms e.g. happier staff may translate to less sick leave, which can be translated into monetary saving. Both the APM Body of Knowledge and PRINCE2 note that benefits must be measureable to enable assessing change resulting from project implementation. Here, an upgrade in best practice for sustainability would be valuable. A wider set of metrics must be adopted, allowing assessment beyond monetary terms only (Iacovidou et al., 2017b). Non-monetary values are already part of appraisal and evaluation of policies, projects and programmes in the UK (Treasury, HM, 2018) and should be rolled out into project management guidelines and adopted consistently across government and industry.

Academics have successfully translated research into impact, making business cases that convinced actors outside academia to integrate research outcomes into their activities. In the UK these successful business cases are reported within impact case studies under the Research Excellence Framework (REF). Reviewing impact case studies on circular economy, resource recovery and waste management from the last assessment round in 2014 (Supplementary information D contains the list of impact case studies assessed here), it is noticeable that the development of successful business cases and delivery of impact takes time (ca. ten years). All elements of business cases (APM, 2012; Office of Government Commerce, 2005) were present across impact case studies, but not all elements were found at all or in equal measures in every case. Technology focused cases provided evidence for option- and investment appraisal such as expected technical viability, benefits and financial return (e.g. evidenced by pilot plants/commercial trials). Other cases provided a solution to one part of a business case, for example, developing an evaluation framework to assess benefits or risks; or

alternatively, driving forward the strategic case with new economic models. In all cases benefits were measurable. Given that "the focus of the Business Case should be on the *totality* of business change, not just one element of it" (Office of Government Commerce, 2005) the implication is that the business case for resource recovery must integrate evidence from research across disciplines to build up the different elements. It may not be possible to write a full business case at once, but if researchers write the parts that they can and collaboratively build on each other's work, then the writing of a complete business case for resource recovery is feasible eventually. Sustained effort and pragmatism are required.

Even when academics present complete business cases for resource recovery, companies still depend on government interventions to enable change. The results indicated the central role that policy and regulation play. As introduced in Section 2, government should support companies to ensure they have the skills and knowledge to adopt circular practices. In part, government can achieve this through applied, impact- and solution-focused academic projects but this does require further reforms in the academic system that already has come some way from disciplinary structures to increased inter-disciplinary and problem-focused research. Government cannot, however, outsource their involvement completely to academia. It is paramount that they represent society to enable shared value creation, and express the wider social and environmental values that go beyond the direct visibility of individual companies and/or their supply chains. An individual approach interacting with each company directly would be costly, and a sectoral/supply chain approach or indeed the effective implementation of the UN SDGs for this purpose might be more affordable.

6. Conclusions

This study explored how academics can formulate a business case for resource recovery. It is easy to get lost in between the old discourse (that predicates economic growth as a solution to the multiple sustainability challenges) and the new discourse (that suggests integrated environmental, social and economic solutions are needed). Elements of both the old "growth will solve it" and the new multi-dimensional perspectives were represented in themes for the resource recovery business case. From the 37 themes identified by experts, key points to cover in business cases pertain to 1) Expanding the types of values and costs considered from primarily economic to also include environmental, social and technical aspects, and 2) Governmental aspects such as regulatory change and policy integration. Enabling technologies and skills as well as resource security are also important to discuss. The old and new discourses can be bridged by including financial considerations in the business case but expanding that with insight into the environmental and social wins through the preservation of technical characteristics of materials, and suggesting how economic gains can be redistributed to economic, social and environmental growth in an effort to make a truly net-positive, restorative contribution to society and the environment. Writing a complete business case requires expertise from multiple academic disciplines. It often takes years, multiple cumulative publications and sustained effort to complete business cases and translate research outcomes into measurable impact through changed practices outside academia.

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Supplementary information

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