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Achieving Sustainable Biomaterials by Maximising Waste Recovery

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Abstract

The waste hierarchy of ‘reduce, reuse, recycle, recover’ can be followed to improve the sustainability of a product, yet it is not applied in any meaningful way in the biomaterials industry which focuses more on sustainable sourcing of inputs. This paper presents the results of industry interviews and a focus group with experts to understand how waste recovery of biomaterials could become more widespread. Interview findings were used to develop three scenarios: 1) do nothing; 2) develop legislation; and 3) develop certification standards. These scenarios formed the basis for discussions at an expert focus group. Experts considered that action was required, rejecting the first scenario. No preference was apparent for scenarios 2) and 3). Experts agreed that there should be collaboration on collection logistics, promotion of demand through choice editing, product ‘purity’ could be championed though certification and there should be significant investment and research into recovery technologies. These considerations were incorporated into the development of a model for policy makers and industry to help increase biomaterial waste recovery.

Keywords

Interviews, Expert Focus group, Waste, Biomaterial, Policy, Legislation

1. Introduction

The biomaterial industry in its broadest sense includes all products derived from plants and animals including natural fibres, oils and waxes, bio plastics and biofuels. According to industry surveys, biomaterials will play a prominent role in future global economies (Vandermeulen et al., 2012). Based on the assumption that they have fewer negative impacts and can be replenished from a wider range of sources, they were historically hailed as ideal replacements for petrochemicals (OECD, 2001). However, questions soon surfaced regarding their sustainability, with key concerns including emissions from land use change (LUC) in shifts towards biomaterial production, as well as those linked to excessive fertilizer, pesticide and water use, and displacement of people and food (Tilman et al., 2009, Searchinger et al., 2010). These concerns are especially important because despite on-going debate surrounding its definition, 'sustainability' has momentum in industry as a business principle, a marketing tool and a legislative requirement. As such, it is imperative that biomaterials are seen to be sustainable (Boer, 2003, Golden et al., 2010).

In response to these concerns, sustainability assessments were developed including e.g. the European Union's (EU) Renewable Energy Directive (RED) and the Roundtable on Sustainable Palm Oil's (RSPO) sustainability standard which target consumable biomaterials (fuel and food) and focus on the impacts of sourcing, processing and transporting feedstock. Such schemes are nevertheless inadequate in terms of capturing a complete picture of the impacts of non-consumable biomaterials like bio-plastics and natural fibres, which also need to factor in the impacts of disposal.

The waste hierarchy sets out a pathway of options to reduce the impact of waste. This study focuses on the ‘recovery’ aspect of the waste hierarchy to identify how waste recovery of biomaterials could be made more widespread. The term ‘biomaterials’ is used in this research only to refer to plant based products such as natural fibres, paper, and bioplastics and everything in between. Fuels, food and garden waste are outside the scope of the research..

1.1. Biomaterials

Combined, the biomaterials industry is vast, contributing a turnover of 2 trillion Euros to the EU economy per annum (Lieten, 2010), so it is important to define with which part of the industry this research is concerned. Compostable bio-waste such as food and garden waste is part of the biomaterials landscape. However this has a relatively mature waste management strategy within European Union policy[1] and it is the subject of significant academic research even having academic journals devoted to it[2]. As such, compostable bio-waste poses different challenges to other less regulated biomaterials, and is therefore not discussed in this paper

Despite representing a relatively small proportion of the overall market, the overwhelming majority of research into biomaterials focusses on biofuels, partly because biofuels are becoming more mainstream but also because of the RED (Gallagher, 2008). The research presented here concerns only the lesser studied non-consumable biomaterial products.

Biomaterials have not been comprehensively studied within the sustainability literature. However, predictions by the National Non Food Crops Centre (NNFCC, 2012) suggest that

[1] http://ec.europa.eu/environment/waste/compost/index.htm

[2] http://www.journals.elsevier.com/international-biodeterioration-and-biodegradation/

the UK biomaterial market could triple over the period 2012-2015. A cavalcade of research on non-consumable biomaterials may therefore be expected, and so establishing a framework for designing interventions to promote their waste recovery, and therefore improve their sustainability, is both a timely and vital exercise.

1.2. Biomaterial Waste Recovery

'Recovery' is used in this paper to refer to disposal options that avoid landfill as per the waste hierarchy; reuse, recycling, incineration with energy recovery, conversion into a liquid fuel like bioethanol and composting. Research suggests that that whether a biomaterial is sent to landfill or is recovered through any of these methods can influence its life cycle impact on CO_2 emissions up to the same degree as other more conventionally studied issues such as the amount of fertilizer used or LUC (Glew et al., 2012, Shen et al., 2010, Ross and Evans, 2003). Currently the UK recycles less than 32% of its textiles and plastics (including natural fibres and bioplastics) yet it manages to recycle 42%, 44% and 75% respectively of glass, paper and steel packaging (European Commission, 2009). Further recovery via incineration of municipal solid waste (including biomaterials) in the UK is only around 10% according to the Chartered Institute of Waste Management[3], virtually no biomaterials are currently converted to ethanol since the technology is still embryonic (Schmitt et al., 2012) and only food and gardening wastes are commonly composted, all of which indicates there is room for improvement in biomaterials recovery.

Recovering waste products can improve supply chain security and have cost savings (Lynes and Andrachuk, 2008, Sacramento-Rivero, 2012). The recovery of waste is therefore taken seriously, as can be seen in Table 1, which gives a summary of European Union (EU) waste

[3] http://www.ciwm.co.uk/CIWM/InformationCentre/AtoZ/IPages/Incineration.aspx

legislation that has been variously enshrined into UK law. No specific legislation to tackle biomaterials has been developed as of October 2012.

Year	EU Legislation	Summary
1994	Packaging and Packaging Waste Directive	'Producer Responsibility' principle founded, set out targets for reducing packaging and to recover 80 % of packaging (including incineration).
1999	Landfill Directive	Regulations for what can be admitted to landfill, restricting biodegradable waste but permitting all other biomaterials.
2000	Waste Incineration Directive	Regulated the emissions caused by the incineration of waste to produce electricity including biomaterials like textiles etc.
2003	End of life Vehicle Directive (ELV)	Fines for producers not achieving recovery targets of up to 90% prompting companies to use more easily recoverable biomaterials.
2006	Waste Electrical and Electronic Equipment Directive (WEEE)	Similar to ELV resulting in incentives for design for disassembly.
2008	Waste Framework Directive	Clarified responsibility for governments, waste producers and managers to promote prevention, preparing for re-use, recycling and other recovery (no explicit reference to biomaterials).

2. Research Design and Methods

This research uses a qualitative, mixed methods approach comprising interviews with biomaterials industry representatives, and an expert focus group. Findings from interviews were used to construct three scenarios to promote the recovery of waste biomaterials, which were then evaluated during the focus group. Each of the methods used is outlined in detail below, and complied with the Economic and Social Research Council's (ESRC) Six Key Principles[4] for research projects, ensuring an ethical approach appropriate to the nature of the study.

2.1. Interview Method

[4] http://www.esrc.ac.uk/_images/Framework_for_Research_Ethics_tcm8-4586.pdf

Opportunities and barriers to biomaterial recovery are difficult to explore with quantitative assessments and so qualitative, semi-structured interviews were used (Neuman, 2004), allowing questions to be asked around pre-determined themes in a conversational manner (Gillham, 2005). The biomaterial industry in the UK was chosen as the focus of data collection because this is where the researchers were located, because waste legislation and sustainability assessments are relatively common, and because the UK comprises a range of representatives of this diverse market: from small independent companies to large multi-nationals. Products made from biomaterials are as diverse as cotton T-shirts to car panels, so it was important to collect the views of a wide range of industry stakeholders to cover this spectrum. The choice of the UK industry provides a useful case study, although the different waste profiles of EU member states mean that specific results may differ from country to country.

Non-probability sampling was employed, gathering the insights of company representatives with specific insider knowledge (Flowerdew and Martin, 2005). There were no existing networks of biomaterial industry-research collaborations available, so leading companies in the industry were contacted directly and from these initial contacts snowball sampling was then used, taking recommendations to widen the sample and avoid further cold calling (Neuman, 2004). The sample size was defined when new interviews unearthed little novel information (Flowerdew and Martin, 2005).

Target industry groups were based on considerations in the WEEE and the ELV where ‘producer responsibility’ is assumed, manufacturers must pay for waste recovery, and retailers may facilitate take back schemes (European Commission, 2003, European Commission, 2000). Therefore, manufacturers and retailers were invited to take part in the research. Engaging with employees that have strategic understandings of companies has been shown to be important, so operational or sustainability managers were approached (Pagell, 2004). Feedstock growers are inherently involved in the sustainability of biomaterials so growers were also invited to participate (Black et al., 2011, Gallagher, 2008). Attitudes of consumers are important as they play a role in product disposal. However, since this falls outside the remit of producer responsibility, collecting consumer opinions was outside the scope of this study. The sample thus constituted a wide selection of stakeholders, so conclusions with multi-stakeholder implications may be drawn. A summary of the company profiles is shown in Table 2.

Table 2 Interview Sample Demographic

Company Classification	Description
Growers (n=4)	Small scale less than 1,000 acres, both food and biomaterial feedstock.
Small Manufacturers (n=5)	Use raw feedstock or processed biomaterials, sell to UK consumers and industry, less than 500 employees.
Large Manufacturers (n=3)	Use raw feedstock or processed biomaterials, sell to UK and international consumers and industry, more than 500 employees, multinational supply chains
Large Retailers (n=2)	Sell a range of processed biomaterials and non-biomaterial products in the UK, over 1000 employees, multinational supply chains

Interviews took place in spring 2012. Preference was for face-to-face interviews or video or telephone interviews if it was not possible to meet in person. Participation was encouraged by providing a concept note via an email invitation, followed by telephone reminders. During the interviews notes were made and written up afterwards, in addition to an audio recording being taken where permission was granted, in order to enable fact checking. The interview protocol was iteratively upgraded with each interview without altering the focus or content. For example, a standard introduction to the research was given to each interviewee after the first interview revealed this would be helpful. Forty-one companies were contacted and fourteen agreed to an interview, giving a response rate of 34%. Appendix I identifies the role of each interviewee and their sector.

Literature on response rates applies mainly to probability sampling where rates range from 30% to 85% depending on the number of reminders sent, respondent age and occupation etc. (Hocking et al., 2006, Regula-Herzog and Rodgers, 1988). Data on non-probability interview response rates similar to this research are not found since biases resulting from low response rates are less likely to influence non-random sampling. The non-respondents were not from any one group in particular and respondents came from each of the main categories of retailers, manufacturers and growers in additional to there being representatives from large multinational and smaller organisations. However despite this there were a substantial number of non-respondents which could have resulted in some degree of selection bias.

Following the final interview, a post analysis summary was sent to each interviewee and they were encouraged to identify any changes needed to the record of their responses (Brenner et al., 1985). All interviewees were content with their documented answers and no changes were suggested as a result.

2.2. Focus Group Method

Following analysis of the interviews (described in detail in section 2.3) three scenarios were developed which were then presented to an expert focus group. Scenario-based stakeholder engagement is a useful tool for qualitative analysis comparing preferences between groups (De Lange et al., 2012, Morgan-Davies and Waterhouse, 2010, Tompkins et al., 2008).

The focus group was held in summer 2012 and targeted UK experts with experience in the biomaterial, waste and sustainability sectors. Focus group participants were identified by conducting an online review of research and government organisations active in the field of biomaterial recovery. Following this, snowball sampling was employed to widen the pool of contacts. Experts had a strategic understanding of their organisation as characterised in Table 3.

Table 3 Focus Group Sample Demographic

Organisation Type	Expert's Role
Research facility for deriving high value biomaterials from plants and bio waste	Director
University department for sustainability research	Director
Consultant to government departments and Co-founder of a sustainability certification scheme	Consultant
Government funded waste organisation	Project Manager
Consultancy advising the UK government departments specifically DEFRA on waste and textiles	Technical Consultant
University environment department	Teaching Fellow in Environmental Economics
University department for industrial uses of plants (biomaterials)	Research Chair
Not for profit research institute promoting global sustainable development	Director
Not for profit research institute promoting global sustainable development	Senior research associate

The focus group experts were introduced to the research via a concept note and a two-page summary of the interview findings. In total, nine experts attended (a response rate of 26%) which is a useful size for data collection in exploratory research (Billson, 2006, Tang and Davis, 1995). The three scenarios: 1) do nothing; 2) develop legislation; 3) develop certification, were discussed over a period of 2.5 hours. Despite differences of opinion between the experts, consensus was reached on the views to be recorded. Following the focus group, a summary of the outputs from the session was sent to all attendees who were asked to provide feedback. Detailed comments were received from one expert. A further nine experts unable to attend the day but who showed an interest in the research were sent a copy of the output summary from the focus group and were asked to comment via a telephone interview or by email. Two replies were received.

2.3. Data Analysis

The use of coding to categorise comments from interviews and focus groups forms the core of the analytical techniques used in this research (Neuman, 2004). Codes were chosen because they reflected the purpose of the research and were both etic and emic, meaning key words and common themes were used in categorisation (Holsti, 1969, Flowerdew and Martin, 2005). Coded comments were organised hierarchically using axial coding according to the book title, chapter and sub heading analogy proposed by Gillham (2005). Once the coding of the interview data had been done, descriptive quantifications of the number of times particular codes were raised could be undertaken. Beyond this, semiotic clustering and a semiotic square was used so that related codes could be defined into to more distinct classifications to identify mutually exclusive and duplicate codes, to align opinions with specific company traits and allow the identification of the scenarios (Flowerdew and Martin, 2005).

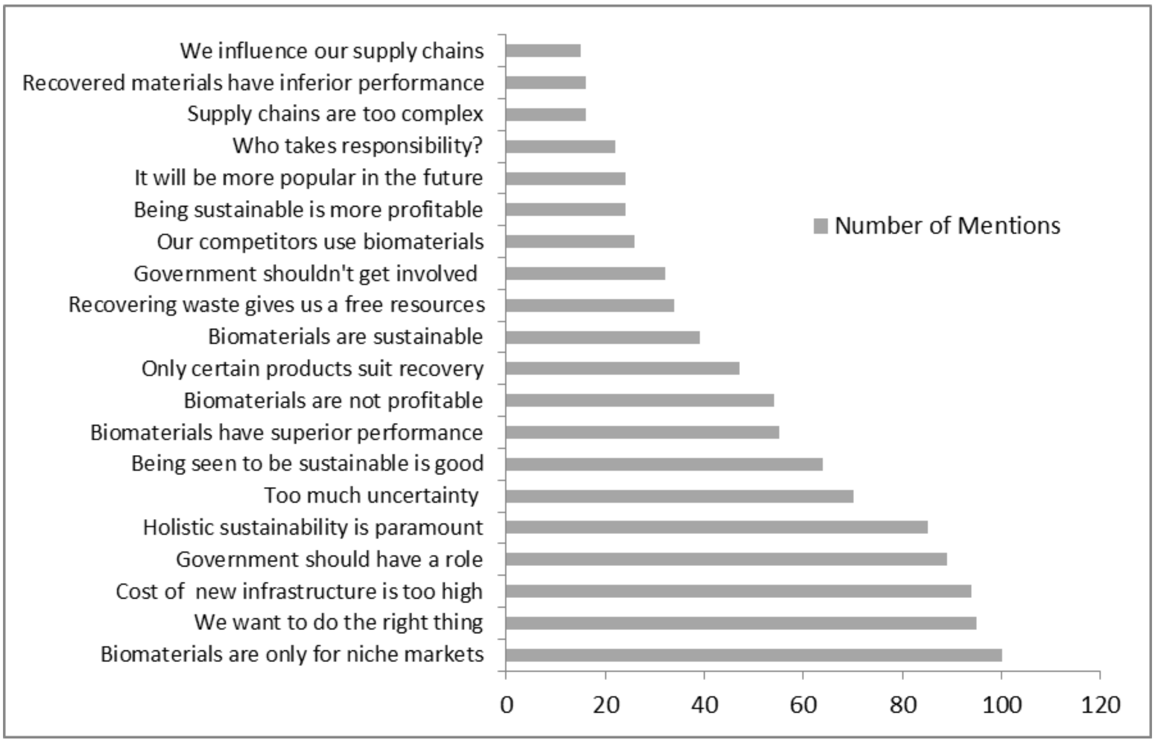
To analyse the focus group data, experts' discussions on the scenarios were noted and their comments were similarly grouped into codes to identify the underlying themes, the areas of consensus and the variation of opinions that existed regarding the scenarios.

3. Results and Discussion

3.1. Interviews

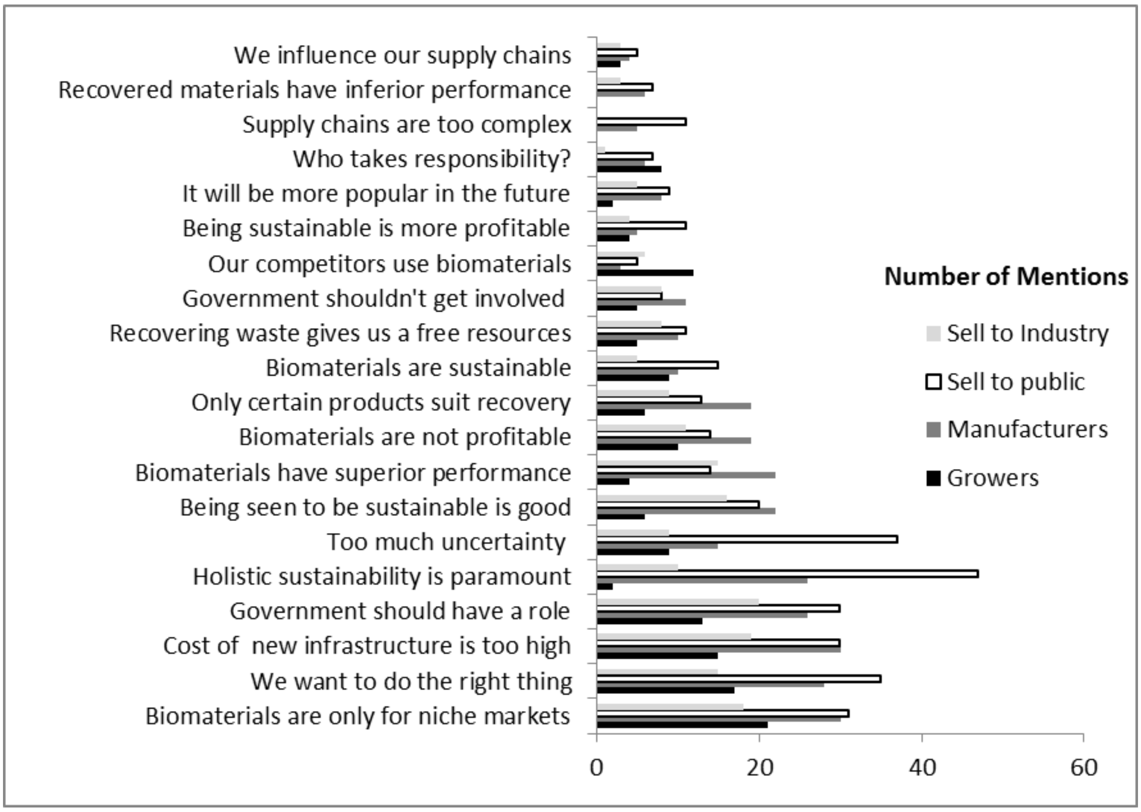
Figure 1 presents a summary of the interview findings according to the number of times a particular theme was mentioned. This quantitative assessment is useful to introduce the issues that were raised and to group them under broad headings e.g. “uncertainty”, “markets”, “ethics” and “cost”. It is important to note that the number of mentions is not an indication of ranked importance and many contradictions were apparent. For example, “government support” was mentioned frequently in some form, though those mentioning it differed in their opinion as to whether it was necessary or not.

Figure 1 Key Themes Emerging From Interviews



Certain trends are apparent when attributing the frequency of mentions to respondents’ stakeholder groups (Figure 2). For example, those selling to the public had a greater preoccupation with ‘greenwash’ and addressing holistic sustainability; they noted the uncertainty of distinguishing ‘good and bad’ biomaterials; and felt their supply chains were difficult to influence compared to those who only sold to other industries. Manufacturers often mentioned costs, were most vocal on rejecting the need for government involvement and said they would only use biomaterials because they served a particular function, not because of their perceived sustainability.

Figure 2 Key Themes in Interviews According to Company Type



There are clear differences in priorities for stakeholders and picking out the interesting trends beyond these prosaic patterns requires qualitative analysis. During the analysis of the interview data it became apparent that the interview responses could be usefully presented under the following two headings: the need for intervention and possible interventions.

3.1.1. The need for intervention

According to the interviews, companies' main concerns were financial sustainability, followed by issues including product quality, risks and environmental footprints. After these common priorities there was some divergence, for example, concerns over stable supply chains, social welfare, habitat destruction, climate change and depleting resources were recorded mainly by companies with international operations. Only a few large retailers and small manufacturers considered waste recovery to be important and these were companies that had an economic or marketing interest in it. A lack of priority for recovery was especially evident for companies selling products that use energy, such as cars, houses or washing powder, whose main life cycle impacts were the in-use energy consumption of their products. It was common that life cycle assessments (LCA) on individual products had not been performed, either because it was too expensive, because companies did not see the need to, or because it was too great a task, especially for those who sold thousands of different products. Several larger firms had performed holistic LCA of their entire company operations but the majority of respondents were confident, even without having done product or company wide LCA, that disposal represented one of the smaller, if not the smallest, environmental impact of their operations. Despite this, several respondents claimed to be interested in disposal and almost all anticipated that it would become more significant to their business in the future. However, in the short-term at least, more pressing problems push waste disposal further down their agenda.

Recovering biomaterials can be profitable, for example, where it provides a free resource in the case of reconstructing natural fibre carpet tiles. Generally it was suggested that recovery is rare because of the low economic value of recycled biomaterials compared to synthetic alternatives. There were also concerns that the reprocessed biomaterials may not have sufficient quality. For example, a retailer investigating the sale of clothes made from recycled natural fibres was concerned they are not always comparatively comfortable, and was reluctant to offer a lower quality product to consumers. This finding confirms that of Nicolli et. al. who also established quality was a barrier to finding markets for recycled products

(2012). Similarly, car manufacturers claimed they were restricted in using recycled products in components such as seat belts due to health and safety legislation. Interviewees felt that technological advancements may be needed to produce cheaper, higher quality recovered biomaterials before they become profitable and desirable enough to be mainstream products.

Companies with many sites, large shop footprints, car parks and who may already be providing recycling facilities for e.g. glass and plastic were particularly concerned that if biomaterial recovery was forced upon them, they would have to take the brunt of the logistical burdens for the rest of the industry. One such respondent stated “we are not a waste management company” and smaller companies even confirmed that allowing larger companies to host their take back schemes for them would be more practical than collecting material on their own smaller premises. A fear of the risks and burdens means large retailers that could arguably benefit the most from recovering large quantities of waste biomaterials to put back into their supply chains, are put off, and are least likely to actually recover any material. Growers appeared most positive about taking back waste, suggesting they drop off raw materials to factories and could simply bring back the waste biomaterial (presumably in composted form) to “put it back on the land and complete the cycle”. Fairness and responsibilities are important issues and how these are shared seems a common barrier that prevents biomaterial recovery rising up the agenda.

Producer responsibility is embedded in waste legislation, yet consumers influence waste recovery too and this was reflected in interview comments ranging from “consumer education is key” through to the notion that any scheme will fail if it places additional cost on “penny pinching customers”. Those accustomed to using various sustainability labels felt that having many schemes running in parallel can be confusing for consumers, and they were not keen on using more labels to promote recovery. The reluctance to place responsibility or cost on consumers seems another reason for the lack of experience and growth in the recovery of biomaterials.

In summary, there are significant barriers to generating interest in recovering biomaterials. These include competing priorities, unknown potential costs and benefits, insufficient knowledge and technical capability, a lack of proven nationwide logistics, uncertainty over responsibilities for recovery and collection, and trepidation about consumer responses. These issues are difficult to tackle with strict intervention and overall, suggested that 'do nothing' was a realistic scenario to include in the focus group discussion.

3.1.2. Possible interventions

Although "do nothing" may be a desirable scenario from the perspective of some companies it has thus far not led to high rates of biomaterial waste recovery. "Intervention" is used here to refer to any form of legislation, investment, law or certification scheme that may stimulate waste recovery. Generally there was concern about government intervention resulting in 'yet more red tape' especially from farmers and small companies who had experiences of burdensome requirements. A cautious overall agreement was nevertheless put forward from larger companies and those accustomed to regulation, suggesting that intervention may be useful. According to an interviewee from the construction industry, intervention would make it easier to "differentiate good from bad". Almost all interviewees across the different stakeholder groups agreed that before intervention on a mass scale is implemented (either from within the industry or from outside), there should be a greater understanding of the risks, logistical requirements and benefits of recovering different biomaterials in different ways.

The interviews revealed that four companies were currently involved in voluntary recovery schemes driven by the desire to "do the right thing" but also in some instances to take advantage of a "free resource". These were: 1) a refurbishment schemes for mattresses though "[they] only do the take back [scheme] on the top of the range models"; 2) leasing schemes for carpet tiles; 3) removal of large bulky items when replacements are being delivered; and finally, 4) a voucher system to encourage consumers to return their clothes to a partner charity shop. These voluntary recovery schemes are in various stages of maturity but all are relatively new, small-scale and not necessarily suitable for all biomaterials. Although the positive impact of voluntary agreements is hinted at by the respondents it has not been conclusively shown in this research, however this suggestion does align with others studies that have suggested they are particularly critical in spurring on technological advancement specifically in the automotive sector (Nicolli et al., 2012).

It was generally agreed by those not partaking in a voluntary scheme that they would require some form of support, such as subsidised costs of infrastructure for collecting, transporting and processing waste, or collective action on a nationwide collection scheme in order to benefit from of economies of scale to persuade them to embark on a recovery scheme. Some form of incentive to stimulate action may have some justification in economic theory since it could be viewed as an attempt to fix the market failure of technological externalities, whereby manufacturers have no incentive to produce items now that consider how they will be recovered by another company at another point in time despite the net benefit to society this may bring (Nemoto and Goto, 2004). Yet beyond the potential benefits of recovered materials being free resources there was no mention by either industry or expert stakeholders that vertical integration of biomaterial producing and recovering companies would be beneficial as is the case on some other markets where technological externalities have been observed.

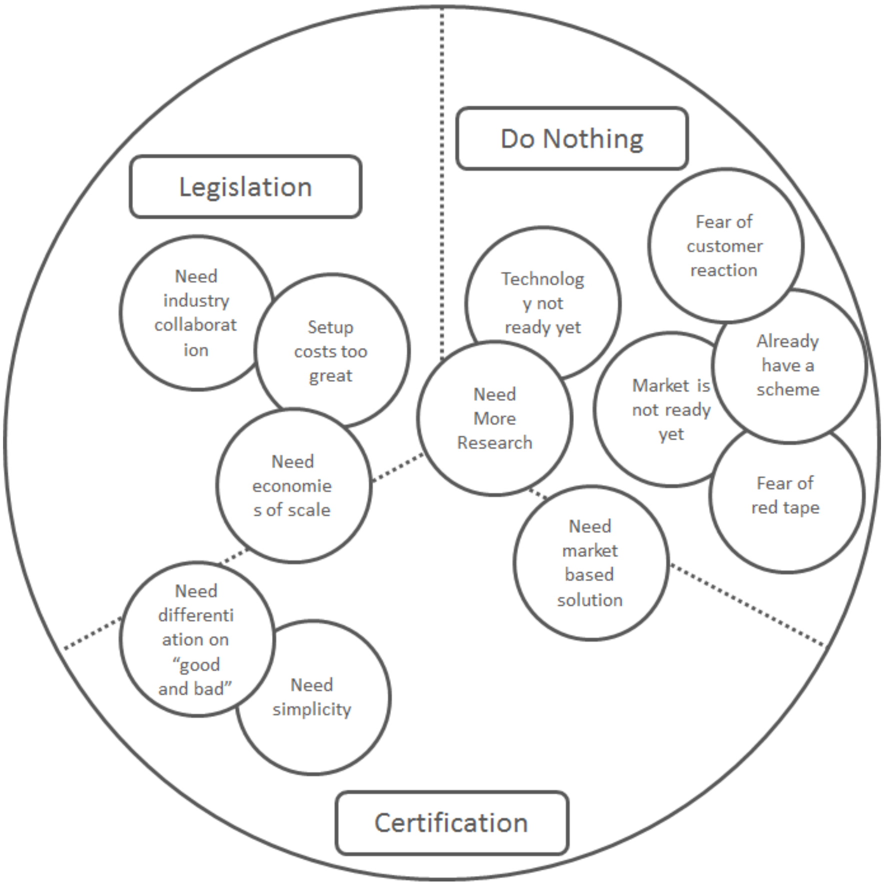
Those companies already involved in a scheme enjoyed their uniqueness and did not crave participation by their competitors, some referring to themselves as “leaders” and enjoying competitive advantage. Thus, although incentives exist to set up recovery schemes, these are unlikely to be sufficient to stimulate recovery on a national scale. As such, “developing legislation” of some kind represents a reasonable scenario to include in the focus groups.

Fear of innovation being stifled by intervention was mentioned by several smaller companies. However, this may be a misconception of the ‘hands-off’ approach, since innovation seemed to be most advanced in the automotive industry where prototypes using biomaterials to increase recovery rates and reduce environmental footprints were more common. At the same time, this is a sector in which waste recovery is heavily regulated (to combat the negative external of sending used cars to landfill), though research and development budgets are generally higher in the automobile industry. The interviews seem to support the assertion that certainty of legislation can stimulate innovation (Office of Fair Trading, 2009), especially where there is momentum behind the technology (Luiten et al., 2006). In the case of the ELV directive, the metals recovered are valuable and so a profitable recycling network collects, sorts and processes end of life vehicles. Biomaterials may not have similarly high market values and individuals from the automotive industry suggested that if other biomaterial producers were forced to recover their products along the lines of the ELV directive, they may end up out of pocket. Assisting recycling companies to extend their capabilities to process all sorts of disparate biomaterial products more cheaply may be helpful yet according to those interviewed one of the benefits of recovering biomaterials is that they provide a cheap feedstock. This means that if they themselves do not directly benefit from recovering the biomaterials, they may not be incentivised to design in recoverability, preferring cheaper petrochemical alternatives.

There was concern from retailers that customers are already faced with multiple forms of labelling and that they may not be ready for additional certification schemes around biomaterial waste recovery, yet the need to segregate biomaterials from synthetics was identified to be a problem by companies from each stakeholder group. For example, a company selling textiles argued there was a need for products to be designed with disassembly in mind, making it easier to break down fibres to their constituent parts without contamination from synthetics before large-scale recovery programs would be worthwhile. Linked to this are the barriers of providing access to collection points and the complexity of self-sorting; challenges that were almost unanimously mentioned. Recovering materials at a large scale is therefore less likely while biomaterials are complex, heterogeneous and difficult to separate. A final scenario for the focus group discussions may therefore be "developing certification", which may incentivise the use of pure biomaterials which will simplify sorting and improve the efficiency of technology.

Figure 3 captures some of the main threads discussed in the interviews. Overlapping circles reflect related themes which are each located in the "legislation", "certification" or "do nothing" scenarios or some combination of all three.

Figure 3 Development of Intervention Scenarios from Interview Comments



In summary, biomaterial industry representatives presented mixed views on the need for intervention. Currently, recovery is being held back because products are not 'pure', the technical challenges and costs of mass recovery are thought to be too great, and there is no guaranteed market for recovered biomaterials, so economies of scale are being missed. Existing schemes are irregular and small scale, though they are indicative of the potential that exists. Despite opposition from some smaller manufacturers there is agreement across the other stakeholder groups that intervention could play a useful role. The scenarios of "do nothing", "develop legislation" and "develop certification" were developed from the interviews and used in the focus group discussions.

3.2.Focus groups

The intervention scenarios taken from the interviews in Figure 3 were presented to the focus group as a starting point for discussion as shown in Table 4.

Table 4 Scenarios for Discussion

	Expand or Develop New Legislation	Voluntary Certification Schemes	Do Nothing
For	The automotive industry is subject to waste regulations which have greatly increased its recovery of materials as a result. The certainty that legislation has brought has spurred on more innovation and could be successful in the biomaterial industry too.	There is a market for sustainable biomaterials that cannot be tapped because of uncertainty. Certification could provide clarity, inform the market and promote best practice within the biomaterials industry.	Change should be allowed to grow organically from within the industry without being hindered by external influences.
Against	There is no ready-made recycling industry to deal with logistical problems of collecting biomaterials as there was for metal in cars. Biomaterials are too diverse to have a one size fits all approach and legislation risks lumbering huge costs onto an emerging market.	Additional certification will confuse consumers adding more labels to already crowded packaging and will not guarantee customers will actually take part in waste recovery.	The costs of setting up a recovery program for mass biomaterial markets are prohibitive, collective burden sharing represents the highest possibility of success and needs some market intervention to make it happen.

Coding of the focus group discussions revealed several overarching principles which held consensus with all the experts. These were: i) that increasing the recovery of biomaterial waste will increase efficiency and sustainability in the industry; ii) that intervention was a reasonable next step to encourage more biomaterials recovery; iii) that interventions should target biomaterials according to their product type not as an overall group (thus recovering textiles in clothes should be approached differently to recovering textiles in furniture and so forth); and iv) that holistic sustainability (not just recommending a particular end of life option) should be promoted. There was also consensus on the general approach of tackling the ‘easy wins’ first, so that effort can be targeted to where it is most effective. Specific blueprints of schemes were not explicitly suggested by the experts, though the following sections discuss their comments on different intervention options.

3.2.1. **Do Nothing**

Allowing the market to act can be an effective means of change yet the option of do nothing was discussed very little in the focus group, despite it being a starting scenario and a relatively well represented stance within the interviews. This may be because of a bias in the sample where only those who had an interest in intervention possibilities that encouraged more biomaterial waste recovery chose to attend the focus group. In concurrence with the majority of the interviewees, the experts generally regarded that something needed to be done to stimulate more waste recovery and that the market alone was not able to bring about the necessary shift in increasing recovery rates.

3.2.2.Legislation

There were palpable concerns for the 'perverse consequences' of legislation, where good intentions can bring about unknown damage. Detailed discussions on the various legislative options that the experts identified are summarised below.

Targets set for recycling and energy recovery have been successful in the ELV directive. However, given the differing waste collection infrastructure, and that cars represent relatively valuable products compared to biomaterials, it was thought that recovery targets and the possibility of financial penalties would be unsuitable for the biomaterial industry.

Incentives were discussed positively for their ability to reward design for disassembly and purer products, especially important when consumers self-sort the products. Specific proposals such as tax relief or direct payments for 100% natural fibre T-shirts for example were not discussed, but the principle of incentives was preferred to that of setting targets.

Bans and taxes were thought to be a hostile form of legislation, though it was mentioned that they have been implemented in some EU member states to penalise those not engaging in biomaterial waste recovery. A case study in France was noted, where textiles companies must either pay a levy on each product they make to help cover the costs of recycling infrastructure, or they must directly fund a recovery scheme with a waste management partner company. The results of this trial were not published at the time of writing[5]. A blanket ban on certain biomaterials being sent to landfill was suggested in the focus group. However, it would be very difficult to differentiate between e.g. plastic and bioplastic bags, and this may result in inequality where biomaterials are penalised more than synthetic products.

Government procurement was suggested as means to stimulate demand for recovered biomaterial products. For example, all carpets and uniforms made from natural fibres could be required to be 'pure', easily recoverable, or sourced from recovered textiles. This proposal was popular in that it provided a relatively unobtrusive approach to legislation, while accommodating the freedom of the market to satisfy demand. It was also seen to assist economies of scale and add a degree of certainty within the market. Having a list of approved products has the appeal of simplicity and is already used by EU governments to ensure 'green procurement' exemplified by the UK Government's Buying Standards that ensure energy efficient appliances are preferred in government departments (European Commission, 2011). It follows that given a government lead, it could be more likely that other organisations would follow suit and apply choice editing to their operations.

3.2.3.Certification

[5] http://www.ecotlc.fr/

Initially, focus group discussions demonstrated limited support for certification because it was felt that each biomaterial would need its own scheme. Multiple certification schemes were thought to introduce excessive complexity for consumers. In addition bio-based certification seen in the USA[6] that ensures a minimum percentage of biomaterial content in products fails to give an indication of potential contamination or the ease recovery or even the most appropriate method of recovery. Support nevertheless grew for the idea as discussions progressed and ideas such as using existing schemes like the European Union's Eco Label certification scheme were discussed. This scheme was already in the consumer landscape and provides an example of a single scheme that covered multiple products. This idea also appeased the requirement to be inclusive of wider sustainability issues which consumers would instinctively expect. Certification was also seen to work well with other complementary forms of intervention, especially government procurement. The inherent complexity of sustainability was mentioned as a potential problem for certification (especially when the purpose of certification is usually to promote single issues). However, it was suggested with little opposition that experts could set the standards behind the scenes and consumers would only need to see the 'logo'. Problems nevertheless remain with this approach; problems that were not mentioned during the focus group. These include the disempowerment of consumers, who may not be aware why a product has been certified. Also, situations may arise where products designed to be recovered easily may not achieve certification if they fall foul of other sustainability obstacles, which could be a disincentive for companies to 'play along'. In addition to not being discussed in the focus group, they were not raised when the experts were asked to comment on a post analysis summary, indicating they perhaps were not important.

[6] www.biopreferred.gov/

One problem that was discussed was that it could not be guaranteed that consumers would actually dispose of their certified biomaterials appropriately. Certification was therefore suggested to be limited to issues such as purity not compostability, which has already seen to cause significant problems for the plastic bag industry. However, it was felt that certification could be effective if targeting the percentage purity or recycled content of a product, and if it is used in conjunction with other legislation (such as government procurement) along with improving access to recovery facilities.

3.2.4.Other Intervention: More Research

Beyond these scenarios other interventions were proposed in the focus group which can mostly be classified as calls for more research. Whether the source of funding should be from government or industry or a combination of both was not discussed. This section describes the types of research that were suggested would be needed prior to intervention.

Logistical knowledge and infrastructure was currently thought to be inadequate to support wider recovery of biomaterials, and research to quantify the amounts of waste for different biomaterials was perceived to be important. Companies do not currently know if they would be inundated with waste if recovery schemes were employed, or if a lack of material would make investment in recovery infrastructure futile. This information could be used in conjunction with research on the relative impacts of different end of life scenarios (recycle, energy recovery, producing fuel etc.) to compile a list of preferred disposal options for common types of biomaterials, as well as enabling cost benefit analyses. It was thought this would assist the compilation of a list of 'easy wins' which would provide simplicity and help focus effort efficiently, being especially useful for government procurement.

A lack of technical knowledge was cited as an important challenge, and improving recovery technologies and capacities was thought to be vital in improving the quality and quantities of recovered biomaterials. An expert from the research sector had experience in running a demonstration plant to investigate new ways of dealing with waste biomaterials with companies who often were unaware of the possibilities. This participant also explained that the research facilities in the UK were still only functioning at a demonstration scale and although demonstration plants are widely used as a means of establishing proof of principle techniques and to improve the collective knowledge commercial companies were needed to invest to take infrastructure to the next useful scale. Once greater awareness and capability is established, costs are likely to fall, increasing the profitability of recovering biomaterials and the quantities consumed. Experts in involved in existing kerb side recycling nevertheless expressed concerns that even advanced recycling facilities and technologies struggle severely with contamination issues, so they may not be able to cope with mixed biomaterials. This hints that technical solutions may not be a panacea.

Public knowledge of the potential for recovering biomaterials was perceived to be low. It was suggested that the majority of consumers would “throw their old holey socks in the bin” without thinking, instead of taking them to a collection bank for reuse or recovery. It was suggested this was down to both limited availability of facilities but also a lack of understanding of the value of waste textiles as new fuels or new fabrics. An education campaign to widen this understanding was tentatively suggested but the unpreparedness of the waste and biomaterial industry to cope with large-scale collections meant that this idea was not thought to be suitable until the industry was better prepared.

In summary, several areas of consensus were identified regarding the design of a proposed intervention: it should be simple, product specific, have few burdens and be economically profitable. Schemes that were discussed are not necessarily mutually exclusive and it may well be advantageous to employ a multi-pronged approach to achieve maximum biomaterial waste recovery. The policy scenario "do nothing" received very little consideration unlike the other two scenarios. "Developing legislation" was seen to have many problems but it found some support where approaches were less strict. The final scenario "develop certification" also received positive comments and was thought to be a useful tool. In addition to evaluating the scenarios, this section has identified useful areas for future investigation. The following section outlines the recommendations that may be drawn from this research.

4. Recommendations

Despite the array of different biomaterial products and companies, and the diversity of comments and opinions collected, this research established a concrete foundation on which to encourage more biomaterials recovery through intervention. This is described in Figure 4.

Figure 4 Model for Maximising Biomaterial Waste Recovery

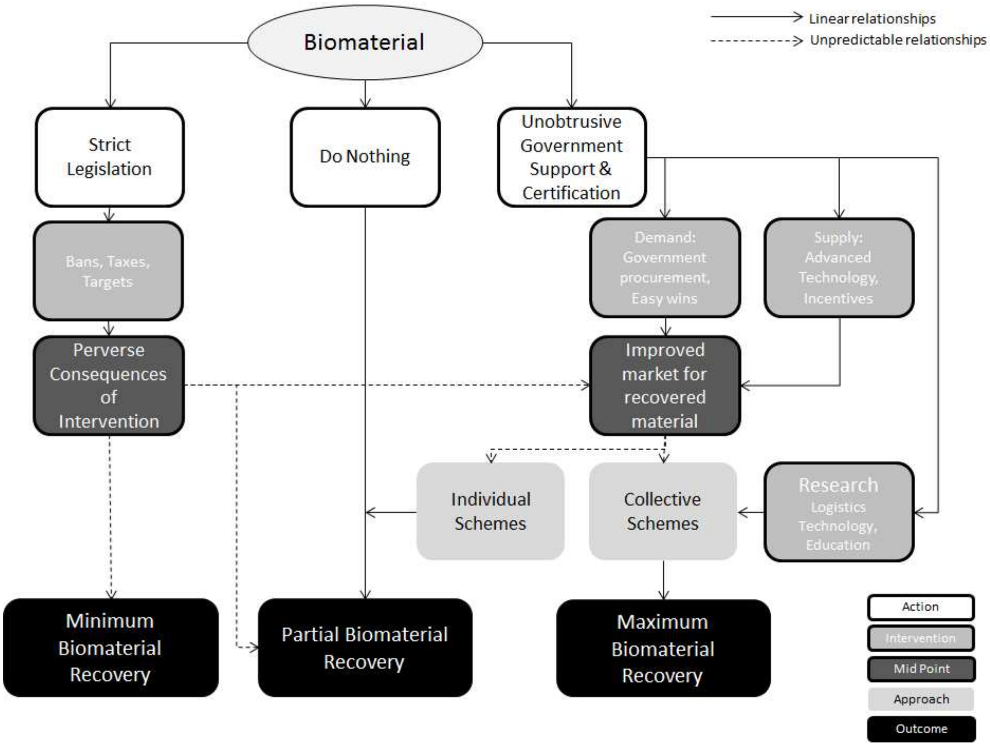


Figure 4 describes the predicted outcomes; minimum, partial or maximum biomaterial recovery of the intervention scenarios, based on the focus group consensus. The "ideal" outcome of maximum recovery is shown to only be delivered by multiple interventions; promoting demand for pure biomaterials through government procurement or certification, increasing the supply of quality recycled materials by developing technology or introducing incentives and finally addressing logistical problems though industry agreements or legislation.

As can be seen, depending on the biomaterial, there may be no intervention required to achieve some amount of waste biomaterial recovery, though this is unlikely to maximise waste recovery. Figure 4 also suggests that improving market conditions for recovered biomaterials may not in itself necessarily achieve the ideal outcome, since logistical and infrastructural issues can still be a barrier.

Strict legislation was less clear in its outcomes, there was uncertainty over the legislation trailed in France and yet it was an unpopular approach with both interview respondents and experts who predicted it should be a tool of last resort. It is likely that strict legislation may achieve some increase in in recovery rates but that it is not the preferred route and so is shown to either produce minimum or partial recovery.

The model in Figure 4 may be especially useful for companies or governments embarking on recovery schemes, as it identifies steps that could be taken (i.e. to improve supply, demand and logistics). It also highlights that although certain biomaterials may not require any form of intervention to promote recovery, in general, multiple unobtrusive interventions may be beneficial, and collaboration, especially regarding the logistics of a nationwide collection scheme, may underpin attempts to maximise biomaterial waste recovery in the industry as a whole.

5. Conclusions

This research has revealed that biomaterial recovery is not currently seen to be an important issue, even though biomaterial waste is highly likely to become more important in the future. Significant barriers to improving recovery rates have been identified which are not being adequately addressed by industry, indicating that some form of intervention may be required. This research has produced a model for policy and decision makers concerned with promoting biomaterial recovery. It suggests the policy scenario “do nothing” may not be appropriate for the entire industry despite its support from the minority already undertaking voluntary activities and that strong regulation such as taxation, fines and targets like those found in the WEEE and ELV directives may have limited and unpredictable success. This is due to the unknown potential market for recovered biomaterials, immaturity of technology and public attitudes, logistical difficulties in collecting biomaterial waste and contamination with synthetics. This research suggests that a lighter touch multi-pronged approach to boost supply through increasing purity of products and the capacity of recovery technology and to stimulate demand through certification or government procurement is perceived to offer an effective way to encourage more biomaterial waste recovery. In addition this study has found that simply influencing the market conditions may not be enough. It is vital in the case of biomaterials to organise and support recovery and collection infrastructure since the diversity of biomaterial products and their particular challenges make spontaneous solutions unlikely, even with a lucrative market.

Appendix I Interview respondent backgrounds

	Interview Respondent Role	Classification	Sector
1	Manager	Grower	Agriculture
2	Manager	Grower	Agriculture
3	Manager	Grower	Agriculture
4	Manager	Grower	Agriculture / Building Materials
5	Consultant	Manufacturing	Carpets and Textiles
6	Director	Manufacturing	Chemicals and Plastics
7	Director	Manufacturing	Textiles
8	Consultant	Manufacturing	Building Materials
9	Research and Development	Manufacturing	Chemicals and Plastics
10	CSR Manager	Manufacturing	Automotive
11	Executive Materials Engineer	Manufacturing	Automotive
12	Senior Sustainability Manager	Manufacturing	Building and Construction
13	Head of Corporate Social Responsibility	Retail	Household and Consumer Products

14	Sustainability Specialist	Retail	Household and Consumer Products

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