

Environmental Impact Reduction for Small and Medium-sized Manufacturing Enterprises in New Product Development

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Abstract

Environmental impact reduction (EIR) in product development can involve numerous activities. In relation to business objectives, the strategic review and integration of EIR should be considered a best practice development opportunity and a contribution towards longer term sustainability. It should be recognised that EIR requirements are often complex and challenging for businesses to implement, especially for those companies lacking the knowledge and resources. This has been found to be the case particularly with Small and Medium-sized Enterprises (SMEs) due to the limitations of available capital and resource. This research was therefore seeking to investigate how to improve practices of sustainable product development in UK SMEs, and in what ways EIR alternatives should have influenced current practices in new product development.

1. Introduction

Small and Medium-sized Enterprises (SMEs) in the UK manufacturing industry represents up to 58% of the total sector [1]. This makes them a significant cause for concern where best practice towards environmental impact reduction (EIR) is a low priority in SMEs. Environmental impact reductive practices are those which consider a responsible attitude towards the use of materials and resources, and take steps to improve the efficiencies of outputs in parallel with company operations. Whereas larger organisations may integrate EIR as part of company strategic objectives in line with their regulatory obligations, smaller organisations however, do not appreciate the intrinsic value of these investments. Due to overly complicated environmental literature; compliance requirements; and infrequent / non-rigorous compliance inspections; a significant proportion of SMEs go unregulated, uneducated and misinformed [2]. Additionally, majority of SMEs are currently not required to improve their practices under government law, due to their size classification being less indicative of environmental threat as oppose to that of larger organisations. Therefore, the levels of environmental impact contributed due to non-compliance within this area are unregulated and uncontrolled.

With EIR for sustainable “new product development” (NPD), this presents a

problematic scenario in that the largest enterprise sector for the UK economy are far from optimised due to lack of awareness and responsibility [2]. Since the majority of impacts of product packaging life cycles derive at the stage of design and specification, such a grey area and lack of responsible practice within SME NPD could present far reaching environmental consequences. By nature, product development is a complex and influential activity where decision makings at the design and specification stages are responsible for up to 80% of all environmental impacts [3]. This raises concern at an SME level, as SMEs have no one fixed mode of operation for NPD due to a lack of overall knowledge and influence within current supply chain systems. This research is therefore focussing on the conceptual design phase at the front end of NPD which is thought to be responsible for initiating around 80% of environmental impacts of any products. The aim is to help SMEs to move away from text heavy environmental documentation, to an approach using visual process mapping techniques to provide a novel method in engaging with complex environmental data in a way which becomes more accessible and tangible to the SME users. If EIR within the SME sector is to be improved, decision making at the design stage must be optimised so that when potentially unregulated packaging enters the supply chain it should create less impact during its life cycle.

2. Literature Review

Every product released on the market utilises packaging in one form or another [4]. According to Vergheze and Lewis [5], due to the volume of packaging required for the delivery of the products to the consumer, packaging will create significant impacts within product supply chains. The excessive volumes of packaging have significant environmental impacts which are not sustainable in the long term. The types of environmental impacts which are to be expected from excessive packaging include: consumption of non-renewable resources; generation of air emissions from production; transportation impacts throughout the supply chain logistics; and the inevitable requirements of solid waste disposal [6]. The relative contribution to this environmental impact from SMEs is additionally considerable, given that SMEs dominate the manufacturing sectors in areas such as: metals, printing, textiles, food, and consumer products, all of which require packaging in one form or another. Since the majority of impacts of a products life cycle derive from the initial stages of NPD specification, a lack of responsible or consistent practice here presents far reaching environmental consequences [2].

NPD is an industry term used in reference to the decision making process of bringing products and services from initial ideation, to the point of manufacture and subsequent market launch [7]. NPD is typically practiced in a linear fashion, involves numerous development stages which require iterations and refinement for a potential product idea. These stages of development are interpolated by a number of phases, which are more commonly referred to as "Gates" [8]. These evaluation gates provide managers with a check point for "go and no-go" decision making during a product's development process, This approach of using gates

within stages of NPD enables management to identify areas where additional attention and resources are needed, in line with the companies' objectives and competencies. The project management process of using stage and gate NPD has been seen by many in both academia and industry, as a major resource for increased sales and improved profit margins within manufacturing, and that the use of a gated multi-stage development process is now being considered as a best practice across much of today's industry [9].

Product and environmental departments within larger companies still seem to have difficulty communicating EIR in a way which fits decision support tools that senior management often use. Therefore, this means that sustainability measurements must be broken down into concrete categories / attributes that can be understood, quantified and addressed to stand a chance of becoming company policy. In particular for SMEs such diversity is not covered by any systematic support, resulting in operations sitting mostly at, or below levels of rated compliance [10]. In order for SME organisations to progress with integrating higher levels of sustainability, it is clear that the financial justification is of significant importance. In order for firms to move 'beyond compliances' they must comprehend exactly how proposed resource efficiencies will lead them to financial and ecological gains [10]. As part of a broader strategy for SME companies to manage their environmental impacts, the European Union (EU) Commission in 1993 developed the "environmental-management and audit schemes", better known as the EMAS regulation. EMAS is voluntary in nature and application is aimed to enable organisations to assess, manage and continuously improve their environmental credentials. Through EMAS, these credentials can be reviewed regularly to provide a basis for managerial decision-making for performance improvements [11].

According to Goodchild [12], the disadvantages experienced by SMEs during EMS implementations revolve around the impact on resources of cost, time and skills for effective practice. Garrett et al, [13] believes that considering the wider system of how SMEs work within their supply chains can help to capitalise on new approaches to networking and entrepreneurship within NPD. Therefore understanding the external influences which place pressure on SMEs, may help to refine how EIR activities can fit into the complexity of current working practices. NPD is a complex activity, not only because of the NPD stages, but also because of the associated environmental impacts. At a strategic level there is a need to map and plan against these. The conceptual design phase at the front end of NPD is thought to be responsible for initiating around 80% of environmental impacts of any product, during its full life cycle of usefulness [2].

3. The Proposed Approach

This paper is focused on using the Delphi Method as an investigation method for gathering data about NPD and EIR from within the SME manufacturing sector. A visual language will assist SMEs when interacting with the complexities of sustainability and its associated documentation, appropriate methods for obtaining

data within this sector, must therefore be able to:

- Show SME levels of current engagement towards sustainable practices within NPD. This will need to reflect regulation procedures, working with others within the supply chains, and any potential best practices currently used within NPD;
- Accommodate the differences between organisational sizes. This will need to reflect the size variances highlighted within the literature review between SMEs ranging from 10 to 50 employees, up to 250 employees;
- Be able to capture the current procedures and practices within the existing supply chains with which NPD is carried out. This will need to clarify how SME organisations carry out their NPD processes, and the variance with which this happens between organisations;
- Identify organisational behaviour characteristics of SMEs. This will need to demonstrate current attitudes of SMEs towards sustainability, and the relevance of sustainability to the organisation.
- Gather the elements required which can inform a visual framework to assist SMEs with day-to-day understanding of complex environmental data. This will need to cover the broad range of relevant information identified throughout the course of the research.

3.1. Process Mapping Solution and Data Collection

This research aims to create a visual framework for SME organisations to support engagement with sustainability practices and regulation procedures by way of process mapping. In order for a visual framework to be effective within the SME community, value from the collected data must contribute to building a framework which aims to:

1. Be comprehensible to SME regardless of their size and experience, for a universal implementation of a proposed framework within the SME sector.
2. Be succinct in relation to internal NPD procedures and relative stages of product development, so that interaction with the framework can be integrated easily within current working practices.
3. Be succinct in relation to external NPD procedures and relative stages, so that the consequences of decisions made can be implemented throughout supply chains with any associated partners.
4. Cater for the placing of the SME organisation within the wider operational system of supply and demand networks, to improve any channels of communication with external organisations.

All relevant data highlighted from the research which will address the following;

1. Current gaps within SME knowledge of better environmental practices and regulatory procedures, which are currently overlooked.
2. Demonstrates clear instruction for the effective implementation of areas which are currently overlooked, in line with existing SME NPD activities.
3. Demonstrates benefit and reward which can justify any engagements of time and resource in the process mapping procedure.

When considering the above aims it is clear there are a number of essential

areas which will need to be individually addressed, to provide a framework which is comprehensive and applicable within SME organisational management structures. One difficulty presents is in getting close to the SME sector for data collection and observation. The current nature of SMEs in literature states that SMEs are typically short of time and resource to engage with additional activity, This currently makes consistent access to professional SME organisations problematic, on a regular basis for those who wish to study their practices. The research will initially need to focus out broadly to discover and confirm key themes and subject areas to be included within the data map, and then focus in without subjectivity. This will be to present the required generic solutions, which are broadly essential to the wider SME community.

3.2 Concept Mapping, Process Mapping and Affinity Diagrams

Key themes from the literature review must be structured to ensure the right questions are being asked of the expert panel. Pickard [13] discusses that one way to approach this is to draw a concept map. A concept map enables the researcher to identify various touch points within the literature and emerging data and begin to link these together in a visual manner. Pickard [13] continues to comment that seeing a picture of emergent key themes prevents an information overload when dealing with complex data information in the form of concept maps.

3.3. Delphi Method

The purpose of the Delphi study is to obtain the most reliable consensus of opinion from a group of experts, by commencing a series of questionnaires which are interspersed with controlled opinionated feedback [14]. Delphi was selected due to the reported accessibility to the target audience, SMEs, being sporadic and inconsistent with quality of input. Due to the nature of the research being emergent, continual critical evaluation was required and thus a stable and professional input was essential. Delphi provided this, by pulling on industry experience over a broad sector that worked directly (and without bias) with the targeted research group, SMEs. Nine companies were involved for the Delphi evaluation The Delphi panels principle trading activities were ranged throughout: Trade Associations in Packaging Design; Research Councils in Packaging Design; Environmental Consultants for SMEs in Packaging Design; SME Businesses from both Food and Drink and Product Manufacturing which rely on Packaging being created on their behalf.

The Delphi investigation was conducted concurrent throughout the research investigation, which would equate to 2 years in total. There were a total of twenty industry experts used through out this duration, which contributed upon the requirements of the project at a given point in time. Nine experts were used for the final evaluation. They were selected on the basis of where areas of concern had been identified within the SME packaging supply chain, of which the final mapping solution aimed to address. Therefore confirmation of improvement from each of

these areas could validate potential positive impact from mapping use, within the current supply chain logistics.

4. Development of the Framework

To illustrate the general complexity of problems which SME manufacturers currently face, an affinity diagram approach was used. The three main subject areas which were identified through the application of an affinity diagram are as follows, which reflect the main concerns as highlighted in the literature review:

1. An overall SME lack of basic knowledge and awareness towards product development sustainability,
2. The complex nature of regulation requirements for SME organisations and the subsequent poor adoption of these practices at an operational level.
3. Low levels of communication between SME organisations, suppliers and the regulation bodies within supply chain systems. This results in poor enforcement and poor adoption of sustainable practices; and the inability to ask informative questions in relation to EIR practices in NPD.

Using the affinity diagram approach helped to identify crossover themes within the data, which bridged each of the three main subject areas:

- An overall lack of education and generic understanding ranging from internal NPD procedures, through to regulations requirements and the ability to engage in conversation and discussion around these topics within the supply chain.
- Inability to self-assess NPD procedures against EIR measurements.
- A lack in understanding of where current SME practices have impacts upon the environment and what is currently available to reduce environmental impacts.

Discussions with the panel of experts using the Delphi method would help to define the following:

1. To verify and define the key areas which SMEs commonly struggle, when integrating sustainability into current NPD. These verified key areas will be grouped into industrial questionnaires, to attain data in relation to key criteria for final mapping proposals.
2. To define overall processes of which SMEs operate when engaging in NPD. This will need to include not only SME internal procedures for product development, but also the external supply chain procedures.
3. To define the overall extent of the government regulations and how these integrate with SME NPD structures. This will be essential in proposing a method to bridge communication between the regulator and the SME.
4. The compiling of this data has enabled the development of appropriate questions for the SME sector, to elicit their current industrial practices.

4.1. Mapping Development

The map in Fig. 1 provided a template where emerging issues in relation to SME NPD, could be assigned to corresponding locations within packaging logistics. This provided a way to visualise clusters of emerging issues against their relative physical location, to enable discussion and further focus. Points "A" to "E"

highlighted the main players within packaging development and the activities at that particular point of the process. Laying out each operation from left to right enables the user to clearly define the various stages, to gain an appreciation of the numerous phases which must be considered when engaging with packaging development. Although generally descriptive, this mapping process fails to incorporate the wider systems of regulation and also the detailed flow of design and specification between areas "A" and "E". Also, no placing of the SME within the wider supply chain logistics is present with larger competitor organisations.

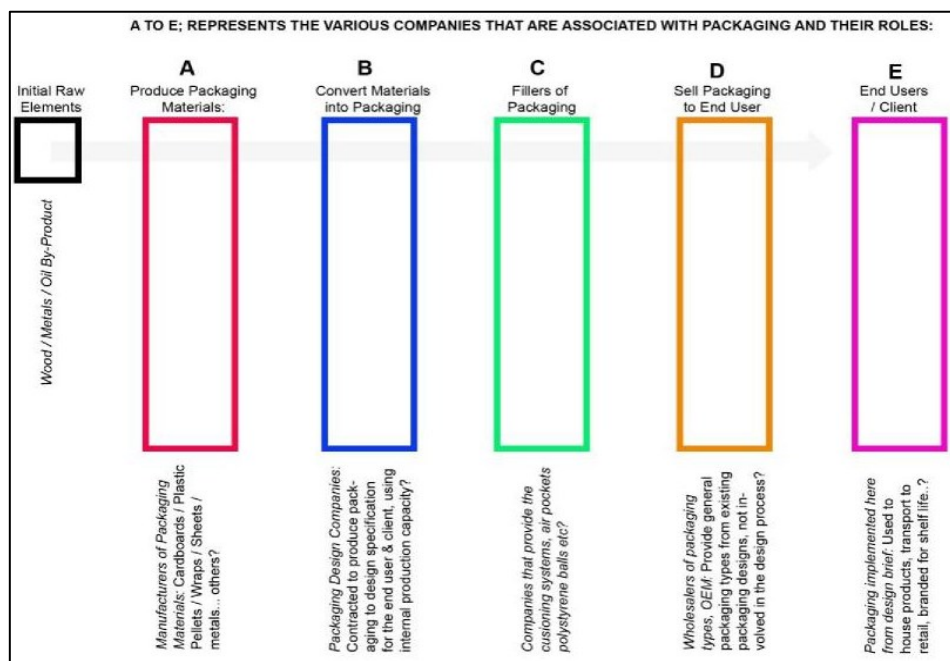


Fig. 1. Mapping development

- System Refinement and Modes of Operation** - It was decided to use the initial process map to reach out to the wider professional community. The objective here was to use the first map to initiate discussion around the common SMEs relate issues with at least six industrial professionals who could also discuss the areas defined when working with the Packaging Federation, and the former affinity diagram's findings.
- Overall Supply Chain Operation** - After consultation with the external panel, the following characteristics of the packaging supply chain were identified and laid out as below in Fig. 2. The packaging supply chain can be broken up from the introduction of raw materials through to the initiation of customer contact.

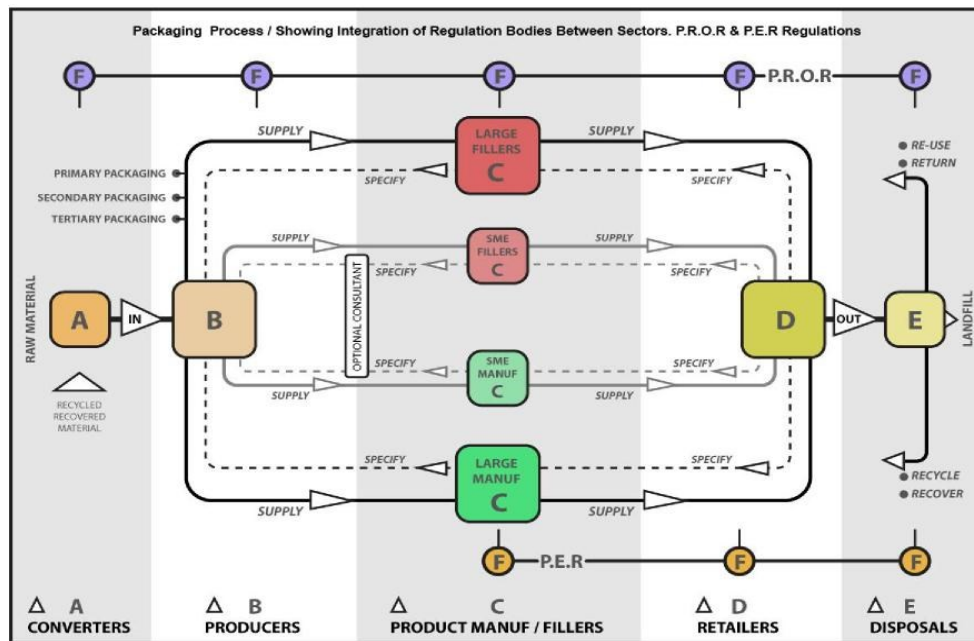


Fig. 2: Flow of packaging design, specification and supply chain

4.1.3 Design and Specification of Product Packaging

The next stage was to use further information provided by the external panel via phone and email correspondence to include the specification procedures between all parties. Including the specification procedures helped to understand who has the design responsibility during packaging creation. Understanding where the design responsibility sits between the SME, supplier and regulator.

4.2 Industrial Questionnaire Essential Criteria

Delphi panel correspondence helped to define the overall packaging supply chain operation for mapping use, and subsequent factors for concern with SME practices.

4.2.1 Refinement of 20 Questions for the Industrial Questionnaire

The supply chain process map was used to provide context on how emerging issues were currently related to the over subject area. Where the affinity diagram holds value in grouping data into categories, the process map now enables these collective issues to be placed into context within a known system of operation. The map demonstrates the ranges of issues which are related to each area, for example: eight factors for improvement with 'knowledge and education', at an SME

level. Working in this manner enables the user to build discussion around exact points of process and highlight key topics which are emerging within the research. As the research project develops, these topics can be edited, removed or built on, at the convenience of new information and data becoming apparent to the user. This method provided a practical engagement with the data, enabling others to discuss the emerging mapping process, SME supply chain operation and problem areas within.

4.2.2 SME Industrial Questionnaire

It was difficult to refine the industrial questionnaire to anything less than 20 questions. It was decided that each of the 20 questions would cover a specific area of the process map and to address a range of activities of which SME companies engage with during packaging specification and EIR. These questions are highlighted as follow:

1. Size of the SME correspondent against the capacity for EIR.
2. If the SME correspondent meets the basic requirements to be regulated.
3. Level of requirement within packaging waste regulations and their obligations.
4. To question the knowledge and awareness of SMEs environmental practice.
5. To question whether regulations are being applied in practice.
6. To understand which resource bases SMEs are currently using.
7. If awareness or engagement with them is encountered.
8. To find out how they manage packaging specific activities.
9. To indicate a range of benefits when SMEs improve their levels of engagement.
10. Business benefits to engage in EIR activity.
11. Potential hurdles which may restrict SMEs from engaging with EIR activity.
12. To understand how connected SMEs are with other organisations.
13. To understand exactly where design is taking place for the SME respondents.
14. Potential design considerations for the development of new product packaging.
15. Levels of communication between SMEs and suppliers of packaging.
16. The levels of communication towards environmental responsibility.
17. What systems are implemented to manage the overall carbon content.
18. Any systems in place to manage SMEs obligations towards packaging waste.
19. Types of toolkits are used by SMEs to manage their environmental obligations.
20. Improving environmental status mean anything to SMEs.

5. Overall Data Results, Sector Trends and Areas of Opportunity

The most consistent response from all those who took part in the industrial questionnaire, was the upmost need to *reduce-costs*, as being the biggest influential factor for SMEs in product development. Alongside this, results indicated that SME companies were positive towards engaging with additional activities, beyond their legal compliance, if it was to provide them with a *business and marketing advantage* against their direct competition. Responses have been positive over all SMEs in relation to moving beyond current levels of sustainability, if actions can be made understandable with *clear benefits which are attainable*.

Over the four size divisions, potential barriers which respondents share revolve around the *lack of understanding* and poor education of *known-benefits* for any sustainable improvements. Any advancement to rectify this is also hindered by restrictive organisational capacities to take on new approaches. These two main points can be seen in all SMEs, where a *lack of clear benefits* and *unclear returns* are rated highly as major barriers. This is also supported by equally high ratings where respondents are unaware of any current *business advantages* to justify improvements. It appears that the incentive and interest to take on approaches towards sustainable development is there in hand, but the benefits for doing so are simply not clear enough. A consistent response from all SMEs appears to be the high levels of importance which have been placed on the potential of *reducing carbon footprints*, as an influential factor for encouraging new procedures. This is an area which packaging consultants voiced was a challenge for SMEs to manage their own carbon levels. Packaging consultants stated that everything is now measured in Carbon content, so this would be of a premium for SMEs who wish to be market as Carbon neutral company.

Within the area of *internal competence* of SMEs dealing with Carbon footprints, only a low level of priority was placed during specifications for packaging with suppliers. The external panel voiced that SMEs lack clout when dealing with their suppliers. Moreover, the reduction of carbon footprints may not only improve aspects for environmental gain, but considerably reduce costs. Reducing costs through better carbon management may also help to *reduce fines*, which also scored highly from SMEs. *Transport efficiencies* also scored highly as an influential area for improvement. Less packaging through design would provide a reduction in cubic efficiency, both reducing carbon content during manufacture and delivery.

Packaging re-use systems were rated the least applied of all practices across the board for SMEs, demonstrating the *lowest* ratings of competence, and the *highest* overall ratings for gaps in knowledge implementation. Previous collaboration with the European Environment Agency stated that re-use systems had become a passing phase with SMEs. Therefore, the re-education for the potential of re-use systems to improve transport efficiencies; reduce the use of resources; reduce overall costs; improve environmental profiles; and significantly reduce carbon content and land-fill, would appear to be largely influential to communicate to SMEs based on responses to these areas being of critical interest to them.

6. The final Framework

The original process map which had been assistive in highlighting criteria for the industrial questionnaire was brought forwards for refinement. As the overall packaging system boundaries had previously been defined in terms of supply chain processes and where SMEs relate to these in context, the appliance of this knowledge could be brought forward as a new framework for data entry. A new system map was drawn up as seen in the *Appendix* using the original supply chain narrative, while expanding each SME question at their respective point in

supply chain process. The figure in the Appendix shows an example of all SME data for all 20 questions, entered into one visual template to represent the responses from the 10-49 sized UK manufacturing SME's. Through the use of the process mapping technique it was possible to break the overall SME sector down into the four different categorical sizes, and observe differing trends within the data for each. Each SME sector size demonstrated its own characteristics in terms of how environmental practices were managed with varied attitudes towards best practice.

7. Conclusion

The overall objective of the process mapping phase was to indicate where specific EIR concerns were most common amongst the range of SME product producers. However, the framework has not been tested with a case study yet. The following information outlines a brief summary of the results for each SME sector size, including areas for improvement, and areas of best practice.

- *SME Sector Size A, 10-49 Employees - Key Areas for Potential Improvement:* Lack of understanding towards packaging sustainability / Lack of appropriate knowledge for packaging specification / Lack of negotiation, collaboration with externals with regards to reducing environmental impacts / Lack of design for disposal / Lack of understanding towards material choice, reduction / No awareness of benefits beyond current compliances.
- *Key areas of good practice:* At best: Managing waste and recycling; Positivity towards change and improvements.
- *SME Sector Size B, 50-99 Employees - Key Areas for Potential Improvement:* Little awareness of others companies and their practices / No awareness of benefits beyond compliance / Lack of negotiation, collaboration with externals with regards to reducing environmental impacts / Appliance of innovation / Lack of understanding towards packaging sustainability / Lack of understanding towards regulations for packaging design.
- *Key areas of good practice:* Managing waste, recycling / Locating new suppliers / reducing Costs / Managing supply chain / Placing a higher priority on the specification stage / Positivity towards change / Comprehension of regulations for waste / Implementation of internal waste systems.
- *SME Sector Size C, 100-199 Employees - Key areas for potential improvement:* Packaging re-use systems / Reducing carbon footprints / Appliance of innovation / Lack of understanding towards packaging sustainability / Lack of understanding towards regulations for packaging design.
- *Key areas of good practice:* Managing waste, recycling / Locating new suppliers / Reducing costs / Managing supply chain / Placing a higher priority on the specification stage / Negotiating with suppliers in relation to carbon reduction / Collaboration with suppliers and external parties for reducing environmental impacts/ Awareness of others / Awareness of business advantages beyond compliances ! Positivity towards change! Comprehension of regulations for waste! Implementation of internal waste systems! Tool kits.

- *SME Sector Size D, 200-250 Employees - Key Areas for Potential Improvement*: Lack of rated knowledge towards packaging sustainability! Little awareness of others companies and their practices! Unaware of benefits to move beyond compliances! Lack of negotiation, collaboration with externals with regards to reducing environmental impacts.
- *Key areas of good practice*: Positivity towards change! Comprehension of regulations for waste! Comprehension of regulations for packaging design! Implementation of internal waste systems.

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Appendix: The overall framework for SMEs EIR

