Identifying abilities needed for industrial sustainability

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Abstract

The purpose of this research is to provide better understanding of the abilities that companies need to improve their industrial sustainability. The research purpose was answered by undertaking the research in two stages, using an exploratory first stage, which informed the descriptive stage. The research is based on data collected in 26 organisations, representing 12 sectors and companies from 8 countries and 162 participants in total. The four abilities of efficiency, internalisation, collaboration and whole system design are identified and defined in this research. The results of the study led to the formation of the framework. Bringing the 4 abilities (themes) that include 9 sub-themes together the researcher proposes the industrial sustainability ability framework. The research has found 4 abilities:

- Efficiency: ability to see environmental and social waste and creatively and systematically reduce them.
- Internalisation: ability to see failed value exchanges and deliberately bring them into the business model.
- Collaboration: ability to look for new types of collaborators up and down and outside current value chain.
- Whole system design: ability to find advantageous connections across the system.

This research has addressed a literature gap and met an industrial need. The primary contribution of this research is to the field of industrial sustainability. This study makes a significant contribution that addresses an under-researched aspect of abilities and how they help companies to improve their industrial sustainability. The research provides understanding of abilities that might be needed to transform from todays position towards a more sustainable industrial system.

Declaration

I declare that this thesis is substantially my own work and no part of the dissertation has been previously submitted to any university for any degree, diploma or other qualification. Previously published work by the author in the form of journal papers and conference proceedings is drawn on for parts of this thesis. When reference is made to the work of others the extent to which that work has been used is indicated in the text and the reference.

This document contains 64,611 words (including references) and 20 figures, and therefore adheres to the limits of 65,000 words and 150 figures put forth by the Degree Committee of the Department of Engineering.

Lloyd Dhilukshan Fernando

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The research is based on data collected in 26 organisations, representing 12 sectors (Automobile, Aerospace, FMCG, Retail, Clothing, Footwear, Carpets, Craft, Furniture, Food & Beverage, Packaging, Ejection seats), companies from 8 countries (United Kingdom, United States of America, Germany, India, Sri Lanka, Vietnam, Spain), and 162 participants in total. The participation of the industrial case study firms has been valuable and instrumental in this research. I would like to thank you all for your time and contribution. Special thanks to Steve Hope, Sanjeev Bahl, Ashroff Omar, Santiago Gowland, Mike Barry, Mahesh Amalean, Hugo Spowers, Jason Kibbey, Dr. Dai Morgan and Dr. Jag Srai for your time and assistance.

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I dedicate my PhD to my Child.

Academic publications by the researcher

Journal paper publication:

Fernando, L. and Evans S. (2015), Case Studies in Transformation towards Industrial Sustainability, *International Journal of Knowledge and Systems Science*, 6(3), 1-17.

Fernando, L., and Evans, S. (2016), Competencies to move beyond eco-efficiency, *Procedia CIRP*, 40(11), 365-371.

Fernando, L., and Evans, S. (2016), Competencies framework to shift to a more sustainable industrial system. *Journal of Cleaner Production* (Under review).

Books

Fernando, L., and Evans, S. (2016), Abilities needed to make manufacturing more sustainable (work in progress).

Conference paper publication:

Peer-reviewed & published

Fernando, L. and Evans S. (2014), Case study of an organisation trying to re-imagine its place in the supply chain: transformation towards industrial sustainability, *International Conference on Sustainable Design and Manufacturing 2014*. Cardiff, Wales, UK.

Fernando, L., Evans, S. and Srai, J.S. (2014), Evaluating capabilities necessary for transformation to sustainable industrial systems: an exploratory case study approach. *11th Wageningen International Conference on Chain and Network Management, Sustainability and innovations in chains and networks,* Capri, Italy.

Fernando, L. and Evans S. (2014), Systems thinking capability essential for transformation towards sustainable industrial system, *18th Cambridge Symposium on International Manufacturing.* Cambridge, UK.

Fernando, L., and Evans, S. (2015), Competencies necessary to improve the ability of organisation to design sustainable future, *International Conference on Sustainable Design and Manufacturing 2015.* Seville, Spain.

Fernando, L., and Evans, S. (2015), Competencies to move beyond eco-efficiency, *13th Global Conference on Sustainable Manufacturing- Decoupling growth from resource.* Ho Chi Minh, Vietnam.

Fernando, L., and Evans, S. (2015), Competencies framework to shift to a more sustainable industrial system. *Global cleaner production and sustainable consumption conference 2015.* Barcelona, Spain.

Conference Poster:

Fernando, L. and Evans S. (2013), Co-creating manufacturing value at whole system level. *EPSRC Manufacturing the future conference 2013.* Cranfield, UK.

Researchers profile

Lloyd Fernando is an entrepreneur with expertise in managing a global printing & packaging manufacturing business. The company manufactures packaging to the retail, apparel & food sector, to the EU & US markets. He has been instrumental in supporting and implementing sustainable manufacturing practices, developing state of the art LEED certified eco-factory and responsible for the global expansion and eco-friendly products and engineering process innovations of the company. His early career was at Ford in the automobile sector as a simulations engineer focusing on process improvements. Where he was responsible for using simulations to determine, maximise, and improve the capacity of the manufacturing assembly lines. His passion for industrial sustainability started with involvement in building eco-factories in South-Asia and involvement in Industrial affiliations such as the sustainable apparel coalition & Sri Lanka Apparel. His industrial experience led to an emphasis to investigate how to transform current manufacturing practices towards a sustainable industrial system. At the Centre for Industrial sustainability, Institute for manufacturing under the supervision of Prof. Steve Evans, he is investigating what abilities do companies need to improve their industrial sustainability.

Education

BSc Computer Science, 2005-2008, Aston University.
MSc Manufacturing Management & Information Systems, 2008-2009, Cranfield University.

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2012-present, Centre for Industrial sustainability, IfM, University Of Cambridge.

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Chapter 1
Introduction

This chapter presents background to the research, the research problem addressed and the aims, objectives, the research question and finally the structure of the thesis is introduced.

1.1 Background to the research

The UK Foresight report, 'The Future of Manufacturing' (2013) highlights the circumstances in which manufacturers will have to operate in future, stating that they will be very different. Environmental megatrends in the form of climate change and population growth, and increased competition for energy, water, and materials, will necessitate significant shifts in the way manufacturers operate. In the face of these challenges, the reactive trends include consumer demands for more sustainable products, and for government action in the form of higher standards around the impact and efficiency of production, and the increasing use of mechanisms to 'price' the impact of production on the environment. This research uses the definition of industrial sustainability as the "*conceptualisation, design and manufacture of goods and services that meet the needs of the present generation while not diminishing economic, social and environmental opportunity in the long term*" (Paramanathan et al., 2004). This implies a holistic approach that supports the three inter-related pillars of sustainability: environmental, social and economic, referred to by Elkington (1998) as the triple-bottom-line of sustainability is needed.

1.2 Research problem

We currently live in a world of constrained resources, growing populations and exceeding planetary boundaries (Tennant et al., 2013; Evans et al., 2009). There is a need for industry to change the way we make things and shift towards a more sustainable industrial system.

Industry need

There is considerable industry literature suggesting a vast gap in sustainability performance between the best (i.e. sustainability leaders in the industry) and other manufacturers, Bocken et al. (2013) present observations of environmental performance between manufacturing plants, which differed up to 500 per cent between worst and best performing factories, where the compared factories make similar products using similar technology. A few manufacturers seeking more long-term solutions to become more resilient are observed to be re-thinking the way things are made. Leaders in Industrial Sustainability have demonstrated significant improvements in their use of materials, water and energy (i.e. improving non-labour productivity). Some manufacturers have already made advances in eco-efficiency, Ball et al. (2015) in the report 'sustainable manufacturing: leading change' state that *"improvements of 50% in energy or water efficiency or 50% reductions in CO2 emissions over a ten year period are common. Others show significant reductions in other emissions such as VOCs (Volatile Organic Compounds). Zero waste to landfill has been achieved by many in the last ten years and those same companies are now focused on reducing waste to incineration" page 2.* Each leader in its sector is observed to be experimenting with interesting ways of improving industrial sustainability, and developing abilities to do things differently. Many others have not yet begun the sustainability journey and lack understanding of the abilities they need to improve their industrial sustainability.

Research need

Concepts such as circularity (Ehrenfeld, 2008; McDonough et al., 2002), systems thinking (Capra, 1996; Forrester, 2007; Senge et al., 2008) and whole system design (Hawken et al., 2005; Anarow et al., 2003; Charnley et al., 2011) provide compelling principles on which future sustainable industrial systems might be built that aid to improve non-labour productivity and resource resilience. There is considerable organisational learning literature (e.g. Argyris, 1999, Senge et al., 2008) but little academic literature and understanding on abilities to improve industrial sustainability. Senge et al. (2008) describes the need for understanding abilities needed to develop learning organisations. Authors do not present a wide range of abilities that might be

needed to transform from todays position towards a sustainable industrial system.

Both in practice and literature there is a lack of understanding of what abilities do companies need to improve their industrial sustainability. Literature providing an understanding of abilities with supporting case evidence is rare. Organisations trying to improve their industrial sustainability by knowing which abilities are needed will be able to become good at those. The knowledge will aid organisations to challenge existing ways they operate.

1.3 Research aims & objectives

The research aims to better understand what abilities do companies need to improve their industrial sustainability.

Objectives of the research:

- Better understand the abilities needed to make manufacturing more sustainable.

1.4 Research question

This research investigates the research question,

What abilities do companies need to improve their industrial sustainability?

The research gaps and the need for the research are confirmed in the literature review.

1.5 Guide to thesis structure

This thesis presents the research in eleven chapters (Figure 1. Outline of the research chapters).

Chapter 2:
Literature review
This chapter grounds the research in the literature. Gaps in existing knowledge are addressed as they form the basis for this research inquiry.

Chapter 3:
Research design

This chapter presents research methodological alternatives considered and reasons for the selection made

Chapter 4:
Introduction to cases of exploratory stage

This chapter presents the case studies explored in the first stage of the research.

Chapter 5:
Analysis of exploratory stage

This chapter presents the high level themes that emerge from the case studies explored in the first stage of the research.

Chapter 6:
Analysis of Efficiency ability (Theme A) descriptive stage

This chapter presents the findings from the second stage of the research. The aim of the chapter is to explore in-depth and identify the sub-themes that comprise theme A. The findings are compared against the existing literature to show it adds new detail and contributions to knowledge.

Chapter 7:
Analysis of Internalisation ability (Theme B) descriptive stage

This chapter presents the findings from the second stage of the research. The aim of the chapter is to explore in-depth and identify the sub-themes that comprise theme B. The findings are compared against the existing literature to show it adds new detail and contributions to knowledge.

Chapter 8:
Analysis of collaboration ability (Theme C) descriptive stage

This chapter presents the findings from the second stage of the research. The aim of the chapter is to explore in-depth and identify the sub-themes that comprise theme C. The findings are compared against the existing literature to show it adds new detail and contributions to knowledge.

Chapter 9:
Analysis of whole system design ability (Theme D) descriptive stage

This chapter presents the findings from the second stage of the research. The aim of

the chapter is to explore in-depth and identify the sub-themes that comprise theme D. The findings are compared against the existing literature to show it adds new detail and contributions to knowledge.

Chapter 10: Synthesis & framework

This chapter presents the bigger patterns in the analysis and the conceptual framework

Chapter 11: Conclusion

This chapter demonstrates that the research questions have been addressed. A reflection on the strengths and weakness of the research and the recommendations for future research is presented. The contributions of the research for practice and research are reinforced to the reader.

Figure 1. Outline of the research chapters

Chapter 2
Literature review

This chapter grounds the research in the literature. Gaps in existing knowledge are addressed as they form the basis for this research inquiry.

2.1 Introduction

In this chapter gaps in existing knowledge are addressed, as they form the foundation for this research inquiry. The research adopts a problem-based reasoning approach to conduct the literature review. The review of the main concepts and what other authors tell us about solving the research problem will enable a description of the knowledge available that is most closely associated with the research study. Reviewing existing knowledge provides current understanding and a foundation for this research inquiry. Through the review of existing theory and concepts the researcher will identify the knowledge gaps within the current body of knowledge. The gaps identified in the existing knowledge then inform the research question. The objective of the literature review is to ground the research question in existing knowledge by addressing the gap it is aiming to close.

2.2 How the Literature Informed the Research Question

Using Science Direct electronic database, books and journals, keywords were coded which helped identify key themes that may contribute towards solving the research problem identified. Initial key words were sustainable manufacturing, resource efficiency, industrial sustainability, whole system design, systems thinking, eco-efficiency, key competencies/abilities for sustainability, educating sustainability professionals and learning organisation. Journal paper and books were filtered and selected by screening according to its relevance to understanding/solving the research objectives. By the use of snowballing technique other disciplines and relevant concepts and different authors and some additional key words (Business model innovation, Sustainable business model, Sustainable value, Value creation, eco-

effectiveness) were found and investigated. Primary Journals including: Journal of Cleaner Production, Journal for Environmental Management, Journal of Industrial Ecology, Journal of Supply Chain Management, Journal of Sustainable Engineering, Journal of Sustainable Higher Education and Journal of Management Science were monitored frequently throughout the PhD process. Key concepts of industrial sustainability were also reviewed to set the foundation for the research enquiry. It became clear that relevant research could come from a number of perspectives such as: sustainable business models, and sustainable value, whole system design. A problem based reasoning with the articles relevance to research objectives was used to filter key papers in addition to its high citation rate, impact factor, author frequency and keywords. During the process of literature review the author was able to understand what other researchers had looked at within the current research area, what theoretical and methodological approaches had been utilised, what the results of these studies were, and most importantly how this informed the current research and areas that required deeper understanding and contribution. Seminal papers were accessed to understand the original principle and recent review papers were investigated to understand surrounding literature and identify gaps in literature.

Figure 2 presents the main research domains identified. It illustrates the interconnection of the research domains; the Industrial sustainability domain explores the key concepts of industrial sustainability, in the systems analysis domain explores techniques such as whole system design, systems thinking and systems innovation approach to the transformation towards a sustainable industrial system. The business models domain explores approaches to sustainable business model development and co-creation of value. The resource efficiency domain explores understanding of eco-efficiency and sustainable manufacturing concepts for tackling resource efficiency improvements (e.g. water, energy and materials) in organisations. The final domain brings together closest fields to the research problem - sustainability competencies and abilities. The aim of the overall literature review is to make sense of the multiple strands that form the foundation for the research enquiry (i.e. **interesting ideas that comes closest to the providing understanding to the research problem**), and to identify key relationships and research gaps that emerge.

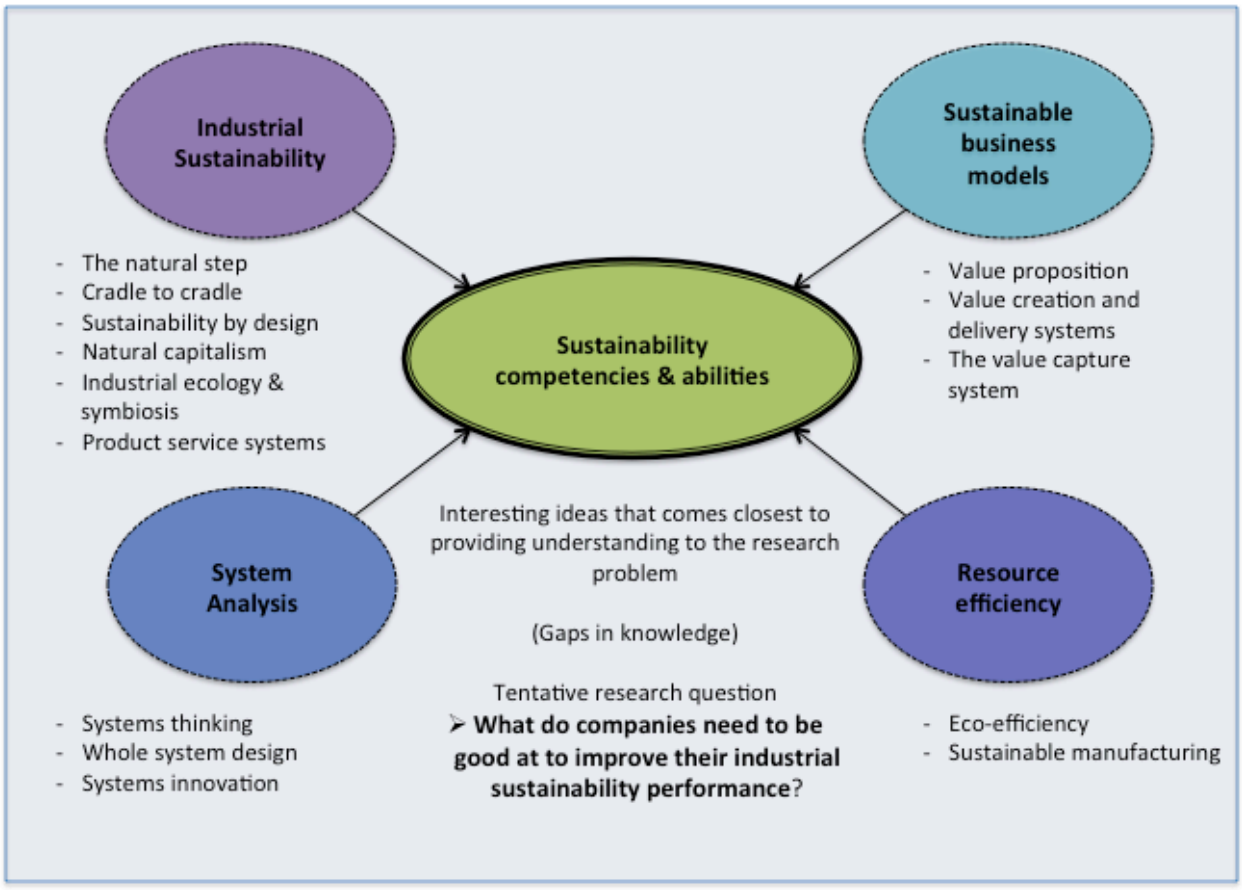


Figure 2. Research domains identified

2.3 Industrial sustainability key concepts

This section discusses a set of selected industrial sustainability key concepts available to business decision makers and academics (Figure 3). Each concept highlights the different views and arguments proposed by the authors. Authors such as Ehrenfeld (2009; 2013), Graedel (1996), Hawken et al. (1990), McDonough & Braungart (2002; 2013), Robèrt (2002) and Tukker et al. (2008) have proposed a variety of mental models and concepts to help understand what sustainability is, how it impacts upon the current industrial system and how the industrial system may have to change.

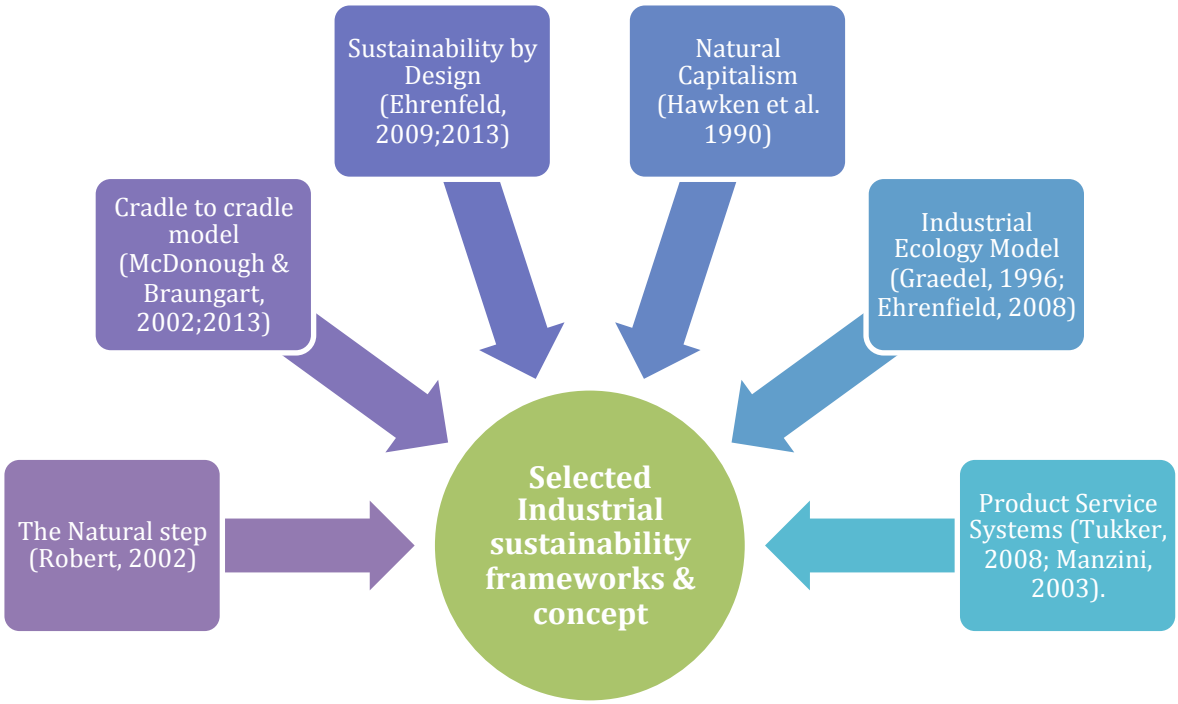


Figure 3. Selected industrial sustainability key concepts - (adopted from Fernando et al., 2015)

2.3.1 The Natural Step (TNS)

Robèrt (2002) defines four system conditions of a sustainable society:

- **Concentrations of substances extracted from the Earth's crust:** The system condition highlights substances from the earth's crust must not systematically increase in the ecosphere, which means that fossil fuels, metals and other minerals must not be extracted at a faster pace than their slow redeposit and reintegration into the Earth's crust. It appears this requires a radically reduced dependence on mined minerals and fossil fuels. This implies there is a need for businesses to make better-informed decisions on which materials are mined from the Earth and what to use less.
- **Concentrations of substances produced by society:** The system condition highlights substances produced by society must not systematically increase in the ecosphere. Nature cannot withstand a systematic build-up of substances produced by humans. It is suggested substances must not be produced at a faster pace than they can be broken down and integrated into the cycles of nature or deposited into the Earth's crust. This implies there is a need for organisations to understand

which unnatural substances does it depend on (e.g., plastics, chemical compounds) and make choices on what to use less.

- **Degradation by physical means, and in that society:** The system condition highlights the physical basis for productivity and diversity of nature must not be systematically diminished. Nature cannot withstand a systematic deterioration of its capacity for renewal.
- **People are not subject to conditions that systematically undermine their capacity to meet their needs:** The system condition highlights for the three previous conditions to be met, there must be fair and efficient use of resources with respect to meeting human needs. Satisfying basic human needs must take precedence over the provision of luxuries when distributing resources.

In the book 'Seeding a Quiet Revolution', Robert (2002) describes The TNS four systems conditions, and provides case examples from organisations. The systems conditions are described to facilitate effective decision-making (Robert, 2002). TNS also emphasises back-casting from the desired end-point (a sustainable society and industrial system) to create a programme of change. The back-casting technique appears to be a valuable communication technique for moving through sustainability discussions while keeping supporters and detractors engaged.

2.3.2 Cradle-to-Cradle

McDonough & Braungart (2002) proposed a cradle-to-cradle concept as a specific form of Industrial Ecology, whereby they separate all materials into either 'biological nutrients' or 'technical nutrients':

- Biological nutrients can be decomposed and allowed to re-enter the natural system;
- While technical nutrients should be kept within the industrial system and used multiple times. The authors have proposed a number of techniques which can be used to define, measure and implement cradle-to-cradle operations.

This concept was made famous by Braungart and McDonough's Cradle-to-Cradle design methodology, which emphasises the switch from a cradle-to-grave paradigm based on a linear production system whereby resources are extracted, modified and

used in the production of goods and then discarded to land-fill at the end of their perceived useful life (McDonough and Braungart, 2002). Cradle-to-grave is commonly associated with an emphasis on end-of-life management (EOL) of a product and extended producer responsibility (EPR); Liefset et al. (2003) argues that this approach is trying to resolve the issues downstream rather than focusing on the upstream causes and the re-design of products so that there are more options than just recycling their component parts or disposing of them. Evans et al. (2015) describe circularity is an approach which stands in contrast to the 'linear' account of traditional production and consumption ('take-make-dispose'), and involves the joining up of the value chain so that end-of-life products are reused as inputs, and waste is utilised as a resource wherever possible. This requires the system-wide design of products for durability, repair, upgrade, reuse and recovery. The authors Mcdonough and Braungart (2013) describe regenerative strategies on upgrading and upcycling energy and resources in the book 'The Upcycle: Beyond Sustainability—Designing for Abundance'.

The concept of a circular economy has become increasingly popular over the last few years with (Ellen MacArthur Foundation, 2013; Kraaijenhagen et al. 2016) all publishing thought leadership writings on the economic potential of it as an alternative to the current linear production system.

William McDonough, architect and co-author of the book Cradle to Cradle, describes the three defining characteristics that we can learn from natural design as follows:

- Everything we have to work with is already here; everything is cycled constantly with all waste equalling food for other living systems;
- Energy comes from outside the system in the form of perpetual solar income; It is an extraordinarily complex and efficient system for creating and cycling nutrients, so economical that modern methods of manufacturing pale in comparison to the elegance of natural systems of production;
- Biodiversity is the characteristic that sustains this complex and efficient system of metabolism and creation; What prevents living systems from running down and veering into chaos is miraculously intricate and symbiotic relationship between millions of organisms, no two of which are alike (McDonough and Braungart, 2002).

The concepts **eco-effectiveness** and cradle-to-cradle design present an alternative design and production concept to the strategies of eco-efficiency. Where eco-efficiency seeks to reduce the unintended negative consequences of processes of production and consumption, **eco-effectiveness is a positive** agenda for the conception and production of goods and services that incorporate social, economic, and environmental benefit, enabling triple top-line growth. It appears from the review that eco-effectiveness focuses on the development of products and industrial systems that maintain or enhance the quality and productivity of materials through subsequent life cycles. The concept of eco-effectiveness also addresses the major shortcomings of eco-efficiency approaches: their inability to address the necessity for fundamental redesign of material flows, their inherent antagonism towards long-term economic growth and innovation, and their insufficiency in addressing toxicity issues.

2.3.3 Sustainability by Design

The relationship between people, products and the industrial systems that develop and deliver those products is explored by (Ehrenfeld, 2009). The author defines sustainability as 'the possibility that humans and other life will flourish on Earth forever. Ehrenfeld (2009) proposed sustainability by design as a set of root causes of unsustainability. This includes the consumption culture and a poor understanding of the complex interactions between people, products and planet and seeks a balanced approach to achieve significant change, while holding onto the best of current systems. Ehrenfeld et al. (2013) describe the importance of caring, as opposed to having and needing, the author argues for the transformative cultural shift that we can make based on our collective wisdom and lived experiences.

2.3.4 Natural Capitalism

Hawken et al. (1999) draw a picture of the 'next industrial revolution' being based on four strategies:

- Radically increased resource productivity;
- Redesigning industry based on biological models with closed loops and zero waste;
- Shifting from the sale of goods to the provision of services;

- Reinvesting in natural capital.

They argue that the growing scarcity of natural resources will act as the catalyst for the next industrial revolution in a similar way that the scarcity of human resources drove the logic of the first industrial revolution. Natural capitalism emphasises a broad and integrated approach to sustainable human activity. Although economic, environmental, and social goals had been conventionally seen in conflict, Hawken et al. (1999) argues, "*the best solutions are based not on trade-offs or 'balance' between these objectives but on design integration achieving all of them together*". Hence, by considering all facets of the problem in advance, business can yield dramatic, multiple improvements and will drive environmental progress. For perhaps the simplest example, using more sunlight and less artificial light in buildings lowers energy costs, reduces pollution, and improves workers' outlook and satisfaction, and hence their productivity and retention rates.

2.3.5 Industrial Ecology Model

Graedel (1996) made a comparison between industrial and natural ecosystems, where Industrial Ecology seeks to position the industrial system within the ecosystem and to emulate that system's ability to use all its wastes as raw material for other life processes. In Industrial Ecology practice we already see many manufacturers using waste from others for their own processes. Ecosystems are properly termed "systems" in part because energy and materials flow between and among trophic levels" (Graedel, 1996). Industrial Ecology (IE) is a metaphor for how industry can learn from observations about how species interact and materials flow within natural ecosystems and at the higher system level the biosphere (Frosch and Gallopoulous, 1989; Ayres, 1989; Scolow et al., 1994; Clift, 1997; Deutz and Gibb, 2008; Ehrenfield, 2008; Ekins et al., 2014). Its aim is to align industrial processes with 'material flows in living systems' (Ehrenfield, 2008) through the reorganisation of firms into 'industrial ecosystems' (Deutz and Gibb, 2008; Lombardi et al., 2012). Scolow et al. (1994) highlights specific dimensions of the industrial ecology metaphor put forward by both (Frosch and Gallopoulous, 1989) and (Ayres, 1989) as; the optimisation of energy and materials within an industrial system, the minimisation of

waste and the exchange of by-products from one production process as an input in another.

The key concepts that emerge from industrial ecology is the idea of the waste or the output of one organism in nature being the input or food for another organism namely the idea of 'waste equals food'. However, Braungart et al. (2007) also emphasises the fact that the concept of waste does not even exist in nature at all. The idea of designing out waste goes beyond the concept of de-materialization which is merely doing more from less material input (Braungart et al., 2007) or designing out aspects of products or industrial processes that produce outputs that cannot be cycled and re-used safely in the techno sphere (Robért et al., 2002) as technical nutrients or enter the biosphere as biological nutrients (Braungart et al., 2007; 2013).

Industrial symbiosis (IS) refers to a 'place based approach' to industrial ecology whereby firms operating within a specific geographical location exchange by-products (Deutz and Gibb, 2008; Boons et al., 2012). One of the most famous and most commonly referred to examples of industrial symbiosis is Kalundborg in Denmark. Eco-Industrial Parks (EIP) are attempts to apply lessons from Kalundborg to other industries and contexts and extends the metaphor of 'exchanging of materials' to 'sharing resources' including both physical materials but also information and infrastructure (Deutz and Gibb, 2008). However it is acknowledged that creating geographically located complexes where industry actors exchange waste is more challenging than it sounds in theory and also designing industry ecosystems based on waste exchange potentially leads to the lock-in of certain practices that produce waste instead of designing out the waste in the first place (Boons et al., 2013; Despeisse, et al., 2012). Chertow and Ehrenfeld, (2012) describes five Industrial symbiosis (IS) models characterised by resource exchanges and the level of environment impact. The five IS models are: 'the build and recruit model', 'the planned eco-industrial park model', 'the self-organising symbiosis model', 'the retrofit industrial park model', and 'the circular economy eco-industrial park model', moving from a low to high level in terms of collaboration and environmental-friendliness (Chertow and Ehrenfeld, 2012). The IS principle encourages supply chain parties to work towards a

high level of collaboration to facilitate environmentally friendly initiatives to be developed and implemented (Bansal and McKnight, 2009).

2.3.6 Product Service Systems (PSS)

Many authors envisage the transformation of existing product-based production systems to systems based on delivering a combination of products and services (or services that provide access to products) (Tukker, 2008; Baines et al., 2009; Neely et al., 2011; Vezzoli et al., 2012; Ceschin, 2014). From the mid-1990s, PSS has become a popular subject for researchers engaged with sustainability and business alike (Tukker, 2015). Authors such as (Stahel, 1982; Schmidt-Bleek, 1994; Tukker, 2015) identify the benefits of the PSS concept in terms of sustainability and resource-efficiency.

The concept of such product service systems is closely aligned with other business models, which reduce material consumption by increasing the information-density of products (where the market value comes to reflect the information, rather than the material content of the product). The primary logic is to sell the function valued by the end customer and remove the current link to ownership of products as the way to deliver value. In most information intensive products the information content provides some additional service function; for example, the value of a mobile phone derives from its communications and other information services and such information systems now constitute a substantial part of the value of many other products, from domestic appliances to automobiles. In general the services or information added to a product contribute to its dematerialisation, reducing the amount of material required per unit of value (Heiskanen, et al., 2003; Tukker, 2015; Vezzoli et al., 2008). Baines et al. (2007) provide examples of PSS; Xerox document management system, which is based on customer payment per print or copy. Total-Care Package offered to airlines by Rolls-Royce plc. Where the company rather than transferring ownership of the gas turbine engine to the airline, leases out ‘power-by- the-hour’ that allows Rolls-Royce to improve engine efficiency, improve asset utilization, and the environmental impact.

A Product-Service System is defined as the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands (Manzini et al., 2011; Vezzoli, et al., 2012). Manufacturers are increasingly experimenting with new ways of meeting customers' needs. This includes shifting from providing products to providing services (Evans et al., 2015). This shift requires the development of new skills, competencies, processes and capabilities that must involve organisational transformation in order to capture and create value (Parida et al., 2014).

2.3.7 Industrial sustainability key concepts reviewed

The researcher, Fernando et al. (2015) at the preliminary exploratory stages of the research compared each of the above selected concepts strengths and weakness in planning for transformation towards industrial sustainability within two participatory case companies. Each concept in turn was presented to the company and discussed, seeking responses on what matched and what didn't match their situation and what might be missing to plan for transformation towards industrial sustainability. The analysis of strengths and weakness of the concept in terms of their ability to explain and encourage transformation toward industrial sustainability is presented. The detailed results are published in JKSS journal refer Fernando, L. & Evans S. (2015), Case Studies in Transformation towards Industrial Sustainability,
(International Journal of Knowledge and Systems Science, 6(3), 1-17, July-September 2015). In summary it was found the various concepts aid manufacturers in navigating their way through the complexities of designing sustainable industrial systems and forming strategy. It is observed that the concepts basic principles for sustainability are essential to guide problem solving and launch system-level planning programs. It was found that the concepts aided the case companies with planning what information is relevant to problems and solutions, and discovering which information is missing. They offer a way to organise thinking and have dialogue around sustainability. The concepts were observed to give the actors in the system a common language and a way to unify their efforts in the same direction from their various areas of expertise. It

is observed that none of the concepts provided clear methodical steps. There was a lack of knowledge on how to implement the ideas and principles proposed.

For example the Natural Step system conditions (TNS) helps to understand whether the system designed is moving towards sustainability or not. The system conditions of the TNS model helps organisations in making better-informed decisions based on the principles. The TNS expert facilitation of the concept 'the sustainability champions training' program for sustainability leadership is described to be effective at helping individuals to see the sustainability challenges and aid organisations understand the relevance of the principles to them and their work (The Natural Step, 2015). The facilitation is described to build the capacity of leaders and participants to act strategically to address the environmental, social, and economic challenges facing their communities and organisations. The TNS program is targeted at creating change makers, participants are described to deepen their sustainability understanding, enhance their confidence as leaders, and be empowered to develop or advance meaningful sustainability projects and social enterprises.

The Cradle-to-cradle concept helps organisations understand the benefits of separating and identifying the biological and technical nutrient flow. It makes the organisation think about capabilities needed for selecting materials, assessment, setting up take-back systems, and exploring service concepts. Capability building, material selection and development of new technologies and the engagement with new alliances is described to be important for cradle-to-cradle implementation (Braungart et al., 2007; McDonough and Braungart, 2002; Kraaijenhagen et al., 2016). Though cradle-to-cradle highlights the importance of developing capabilities. There is lack of practical understanding of what abilities do companies need to improve their industrial sustainability. Industrial ecology concept provides a set of design rules, for example it encourages a lot of thought on pairing up with other actors and organisations and matching material flows. The researcher learned that the selected concept don't provide sufficient understanding of specific abilities needed to implement the visions and systems proposed. The concepts reviewed emphasise the mental model challenge and the need and importance of shifting from the current industrial system towards a more sustainable industrial system, the broader issues of

sustainability in terms of leadership and in terms of change management, and sustainable business models. The importance of doing good business that has a triple bottom line benefit are discussed in the literature while it is clear that an ability-based view is not presented. The researchers view of sustainable industrial system based on the literature review of key industrial sustainability concepts; there is a need to be net zero (e.g. net-zero carbon, significantly reduce environmental impact) or restorative within planetary limits (e.g. creating a healthy atmosphere, flourishing ecosystems, new business models that help regenerate the environment). There is lack of understanding on how to get there.

Authors in the literature reviewed do not present an ability-based view or use that word. The researcher reviewed the literature through the lens of what abilities do companies need to improve their industrial sustainability and has been able to identify some high level abilities from the descriptions in the literature. In this section of the literature reviewed, the researcher has identified some important abilities (Table 1):

Abilities	**Reference**
- Being able to create shared understanding (e.g. TNS back-casting technique (Robèrt, 2002))	(Robèrt, 2002)
- Being able to understand how industry impacts the ecosystem.	(Robèrt, 2002; Ehrenfeld, 2009; Hawken et al., 1999)
- Being able to seek new collaborators (e.g. Industrial Ecology- Being able to exchange waste, by-products and energy with other sectors to make better use of all input).	(Ehrenfield, 2008; McDonough & Braungart, 2002; Despeisse et al., 2012)
- Being able to improve resource efficiency	(Ehrenfield, 2008; McDonough & Braungart, 2002)
- Being able to change business models and find new value offering	(Tukker, 2015)

- Being able to redesign the system	(Ehrenfeld, 2009; Hawken et al., 1999)
- Being able to shift from providing products to providing services	(Tukker, 2015; Vezzoli, et al., 2012; Manzini et al., 2011)

Table 1. Abilities for Industrial sustainability

2.4 Resource efficiency

This section presents some ideas and concepts authors present on eco-efficiency and sustainable manufacturing for tackling resource efficiency improvements (water, energy and materials) in organisations. In the new world of constrained resources, growing populations and reaching planetary boundaries, it is suggested by many authors that we must fundamentally change the way we make things (e.g. focus on non-labour resource productivity across the manufacturing sector). The principle of 'doing more with less' is fundamental to sustainable development and vital to the manufacturing industry's ability to meet future demand. Evans (2015) in a report making British manufacturing sustainable describes the average manufacturer now spends five times more on non-labour costs than on labour costs. It is argued industry efforts should be on improving non-labour productivity (Despeisse et al., 2013; Baptist and Hepburn, 2012; Allwood, 2013).

Researchers as early as the 1960's promoted 'pollution prevention' (Dales, 1968) and the IPAT equation [the multiplicative contribution of population (P), affluence (A) and technology (T) to environmental impact (I)] (Commoner, 1972; Ehrlich and Holdren, 1971). Sustainability requires improved resource use-productivity (Seliger et al., 2008) in order to reduce natural resource inputs as well as consequent waste and pollutant outputs; this reduces the scale of the technology variable in IPAT. Effectiveness is focused on making wise choices with respect to how resources are used.

Technological optimists believe that innovation is a key to produce more with less. Progress would be enough to generate the decoupling of economic growth and impact

on nature (Lovins, 2011). Technological pessimists state that in the context of a much more dynamic and populous world, technology alone is not enough to solve all the challenges (Alexander, 2012). Authors such as (Lovins, 2011; Von Weiszacker et al., 1997) have contributed to understanding the inefficiencies of current industrial systems.

Other authors have viewed efficiency through the lens of organisational routines. Bandehnezhad et al. (2012) sought to provide an understanding of the importance of lean manufacturing in providing environmental benefits to organisations, the research investigates the effect of lean practices in different functional areas of manufacturing firms on environmental performance. (Kissock and Eger, 2008; Seryak and Epstein, 2006) have described how a side effect of implementing lean can be a reduction in energy, but there is little evidence from the literature that organisations are using approaches such as lean for targeting energy reduction as the primary focus. Ball and Evans et al. (2009) explore the challenges faced when attempting to design a zero carbon manufacturing facility. Gungor and Evans (2015) provide understanding of eco-effective changeovers and changing a burden into a manufacturing capability.

Duflou et al. (2012) provides understanding of transition towards energy and resource efficient manufacturing. Minimising the embodied energy in manufactured products is attracting more and more attention as energy cost is increasing as well as the associated environmental impact (Seow and Rahimifard et al., 2013). Beyond energy efficiency in manufacturing, the assessment of embodied energy encompasses more than the energy directly related to the lifecycle of a product: it also shows the importance of material choice and supply chain parameters (Kara et al., 2010).

Modelling and optimisation techniques for resource efficiency have also been studied, with some techniques proven to be a reliable tool to support manufacturing improvements. Modelling and simulation techniques integrating material, energy and waste flows, Ball et al. (2011) suggests can help to understand interactions between processes. Ball et al. (2011) suggests it can be used to make informed decisions to improve resource-use productivity by identifying losses from the system, which can be used elsewhere as a valuable input.

There are concepts for sustainability applicable to manufacturing (Schmidt-Bleek, 1994, 2009; Robèrt et al., 1997; Von Weiszacker et al., 1997; Esty et al., 2009) and numerous examples of sustainable manufacturing practices such as waste minimisation (Clelland et al., 2000; Ball et al., 2009; OECD, 2015), factor four - doubling wealth, halving resource use (Von Weiszacker et al., 1997; Lovins, 2011), energy efficiency (Mackay, 2008; Bunse et al., 2011; Allwood, 2012), energy efficiency through monitoring (Ameling et al., 2010) or through technology substitution (Goldstein et al., 2008; OECD, 2015). Evans et al. (2009) describe cases of companies, which reduced the energy used to make their product by over 40% and have achieved zero waste to landfill. The numerous examples of successful sustainable manufacturing practices in various industrial sectors demonstrate that there are benefits in implementing sustainability improvements (Brown, 2012; Rusinko, 2007; Menzel et al., 2010; Lavery et al., 2013). However, the adoption of sustainability practices is not systematic (Lunt and Ball 2012; Despeisse et al., 2015). Bocken et al. (2013) and Litos and Evans (2015) have contributed to understanding the emerging issue of variation in environmental performance between production sites. The research provides understanding of why factories, which produce the same products, vary in sustainability performance, even within the same company. The paper presents observations of environmental performance between manufacturing plants which differed up to 500 per cent between worst and best performing factories, where the compared factories make similar products using similar technology, all in well-run companies, which have environmental management programmes in place. The authors describes learning within the company between different sites is important but can be difficult. Some initial success stories were observed to include a quid-pro-quo approach between factory sites (teach-learn-do-teach) and dedicated individuals (champions) in factories who strive to make year-on-year efficiency improvements. To improve this situation, authors have proposed various tools, such as (Litos and Evans, 2015) who propose a maturity grid for eco-efficiency self-assessment in factories. Authors such as Despeisse et al. (2011) propose tactics and strategies for eco-efficiency, to improve factory resource and energy efficiency by learning from other companies through their proposed tools. Their paper presents a tactics library to provide a connection between those generic sustainability concepts

and more specific examples of operational practices for resource efficiency in factories. Despeisse et al. (2015) provide a collection of tools for factory Eco-Efficiency. Gupta et al. (2011) describe eco-efficiency approach can be considered the first step in industrial sustainability or in other words a simple way of doing 'good business'. A second stage called eco-effectiveness considers better approaches; focuses on a more efficient use of energy, water and materials as closed-loop processes to eliminate waste streams from entering the environment, considering the product's entire life cycle and practices that restore renewable resources and communities, accordingly to the concept of sustainable supply chains. Evans et al. (2015) state that "*too many managers remain unaware of the extent of the benefits that could be achieved through greater efficiency. Too many firms are structured in such a way that responsibility for resource and energy efficiency is mired at middle-management level, rather than being a key consideration in the strategic direction of the company from the CEO on down. Too many firms are short-termist in their focus and their decision-making, rather than taking a long-term view of the shape of future markets and how they should position themselves to take advantage of this".*

2.4.1 Researchers' view - Resource efficiency

Resource efficiency is a vital consideration for manufacturing industry at present due to concerns over the sources and volatility of supply of key materials, energy and water. Many authors suggest and provide evidence that addressing non-labour resource productivity offers substantial benefit.

The literature and current understanding on resource efficiency emphasises the importance of using resources with care, presenting examples of operational best practices, strategies and tactics for non-labour resource efficiency in factories (example Von Weizsacker et al., 1997; Esty et al., 2009; Lovins, 2011; Despeisse et al., 2011). But no authors were found that studied the specific ability needed to deliver resource efficiency. There is a lack of evidence and understanding of what abilities do companies need to improve their resource efficiency.

Authors in the literature reviewed do not present an ability-based view or use that word. The researcher reviewed the literature through the lens of what abilities do companies need to improve their resource efficiency and has been able to identify some high level abilities from the descriptions in the literature. In this section of the literature reviewed, the researcher has identified some important abilities (Table 2):

Abilities	**Reference**
- Being able to find and implement resource productivity improvements (e.g. increasing the value derived from every tonne of material, litre of water and kilowatt of energy we input into the production process)	Von Weizsacker et al., 1997; Esty et al., 2009; Lovins, 2011; Despeisse et al., 2011)
- Being able to learn from other companies (e.g. broader adoption of best-practice efficiency methods)	(Bocken et al., 2013; Ball et al., 2009)
- Being able to measure and improve the energy and material used	(Ameling et al., 2010; Mackay, 2008; Bunse et al., 2011; Allwood, 2012; Duflou et al., 2012)
- Being able to continuously find improvements	(Despeisse et al., 2015; Litos and Evans, 2015)

Table 2. Abilities for resource efficiency

2.5 Sustainable business models

Bocken et al. (2014) states that business model innovations for sustainability are defined as: Innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organisation and its value-network create, deliver value and capture value (i.e. create economic value) or change their value propositions. It is argued in Bocken et al. (2014) that to tackle the pressing challenges of a sustainable future, innovations need to introduce change at the core of the business model to tackle unsustainability at its

source rather than as an add-on to counter-act negative outcomes of business. The level of ambition of business model innovations needs to be high and focused on maximising societal and environmental benefits, rather than economic gain only. The sustainable business model innovation describing radical changes in the way companies do business has received considerable attention from both academia and practitioners (Chesbrough, 2010; Zott et al., 2011). Sustainability management deals with social, environmental and economic issues in an integrated manner to transform organisations in a way that they contribute to a sustainable development of the economy and society within the limits of the ecosystem. Leaders, managers and entrepreneurs are challenged to contribute to sustainable development on the individual, organisational and societal level. Scholars and practitioners are recently increasingly exploring if and how modified and completely new business models can help maintain or even increase economic prosperity by either radically reducing negative or creating positive external effects for the natural environment and society, literature surrounding this area is scarce and still emerging.

Orgnaisations today are challenged to contribute to sustainable development on the individual, organisational and societal level. Sustainability management refers to approaches dealing with social, environmental and economic issues in an integrated manner to transform organisations in a way that they contribute to a sustainable development of the economy and society within the limits of the ecosystem e.g. (Starik and Kanashiro, 2013; Schaltegger et al., 2012; Boons and Leudeke-Freund (2013). It appears "technological fix" – is insufficient to create the required transformation of organisations, industries and societies towards more sustainability. Researchers and practitioners are therefore increasingly exploring how completely new business models can help maintain or even increase economic prosperity by either radically reducing negative or creating positive external effects for the natural environment and society e.g. (Boons & Lüdeke-Freund, 2013; Hansen et al., 2009; Schaltegger et al., 2012; Stubbs and Cocklin, 2008). This perspective does not only cover existing organisations and how their business models are transformed (e.g. Sommer, 2012), but also entirely new business models pioneered by entrepreneurs. The literature on sustainable business models is still emerging.

The literature presents numerous views on what constitutes a business model (e.g. Richardson, 2008). Teece (2010) provides a concise definition: a business model is the design or architecture of the value creation, delivery and capture mechanism of a firm, how the firm delivers value, how it attracts customers, and how it converts this to profit (Teece, 2010). Richardson proposes a summary organised around the concept of value:

a) The value proposition – offering, target customer, differentiation;

b) The value creation and delivery system – The value chain required, resources, assets, processes, position in the value network relative to customers, competitors and collaborators;

c) The value capture system – How the firm makes money (financial model) and competitive strategy.

Evans et al. (2015) describe manufacturers are increasingly experimenting with new ways of meeting customers' needs. This includes shifting from providing products to providing services, in a way that separates the use of a product from its ownership; or circular economy models where products are designed and manufactured for continuous reuse, and value is captured from 'waste' wherever possible.

2.5.1 Researchers' view – sustainable business models

The sustainable business model literature describes the concept of value proposition and the creation of creative positive benefits to its stakeholders. There a growing volume of industrial cases on sustainable business models, but little is known on how these improvements were conceived, little is available about specific abilities and competencies (Barth et al., 2007; Segalas et al., 2009; Willard et al., 2010; Teece, 2010; Bocken et al., 2014). System transformation and value transformation appear to be importance concepts to the research enquiry. An ability-based view is not presented; though Teece's definition of a business model offers insights on the abilities needed. There is a lack of evidence and understanding of what abilities do companies need to improve their business model for industrial sustainability.

Authors in the literature reviewed do not present an ability-based view or use that word. The researcher reviewed the literature through the lens of what abilities do companies need to improve their business model for industrial sustainability and has been able to identify some high level abilities from the descriptions in the literature. In this section of the literature reviewed, the researcher has identified some important abilities (Table 3):

Abilities	**Reference**
- Being able to innovate and transform business models to create sustainable value (i.e. realise the economic, social and environmental benefits of a more sustainable industrial system)	(Adams et al., 2016; Bocken et al., 2014)
- Being able to capture value	(Bocken et al., 2014; Teece, 2010; Boons and Leudeke-Freund, 2013)
- Being able to improve resource efficiency (i.e. improving non-labour productivity	(Bocken et al., 2014; Boons & Lüdeke-Freund, 2013)
- Being able to shift from providing products to providing services	(Tukker, 2015)

Table 3. Abilities for sustainable business models

2.6 Systems analysis

The industrial sustainability literature reviewed suggests system thinking and whole system design techniques as being one of the critical ways to solve the problem identified. This section presents main ideas on system thinking, whole system design and systems innovation.

2.6.1 Systems thinking

Seiffert and Loch (2005) suggest that the most important property of systems is that they are made up of several parts that are not isolated, but closely interlinked, forming

a complex structure. Systemic or systems thinking, facilitates the improved understanding of these complex systems and enables the identification and utilisation of interrelationships and linkages as opposed to things.

Systems thinking is a technique for investigating entire systems, seeking to understand the relationships, the interactions, and the boundaries between parts of a system (Senge, 2008; Cabrera, et al., 2015). Systems thinking is particularly well suited to modeling highly complex open-systems where an integrated understanding is required at both the micro and macro-levels in order to predict or manage change. This contrasts with the dominant analytical approach of the physical sciences, which is based on reductionism, analysing closed-systems at the level of their constituent parts and then simplifying to draw out general conclusions. Systems thinking is a generic term that spans a range of more than 20 tools and methodologies (Reynolds and Holwell, 2010).

Senge (1990) explains that 'systems thinking' is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots. It appears that system thinking is a way of approaching problems: rather than applying a strict linear methodology, the techniques are iterative, and designed to stimulate investigation, discussion and debate by encouraging multiple perspectives. Systems-thinking does not aim to provide quantifiable answers to specific problems, but rather provides a range of options and better understanding of the implications of those options (Meadows and Wright, 2009; Madrazo and Senge, 2011). Manzini and Vezzoli (2003) emphasises the need for design for sustainability to move from product thinking to system thinking.

Network analysis potentially provides the scope to integrate multiple factors (economic, social and environmental). Preliminary research on analysing sustainability within industrial networks has demonstrated the use of such tools in understanding how and why networks adopt sustainability initiatives and the significance of 'focal' companies within the network (Van Bommel, 2011).

Network Value Analysis (NVA) is a tool to assess business value networks and ecosystems. The tool aims to create a visual map – identifying where value lies in a

network, and how that value is created (Peppard and Rylander, 2006) by;

- Looking at the firm from a value network perspective involves understanding of the nodes within the network (the roles and functions, rather than organisations names),
- Defining boundaries of the network,
- Then focusing on the mechanisms of value exchange and creation within the network.

It is described by authors (e.g. Senge, 2008) that many of the current challenges in industrial systems stem from the inability to understand and manage dynamic systems. Systems Thinking takes a birds-eye view and observes the whole picture by focussing on the relationships between the different entities of a system, rather than on isolated parts. Systems thinking is described by authors (Hawken et al., 1999; Rocky Mountain Institute, 2006; Senge, 2008; Evans et al., 2009; Charnley et al., 2011; Cabrera et al., 2015) as providing the foundation for a proactive approach to be able to design sustainable industrial systems (e.g. Systems Thinking can be a way to understand complex, non-linear, and interconnected systems of businesses, whether social, managerial, economical or environmental issues). There is lack of evidence and understanding of what abilities do companies need to improve their industrial sustainability at systems level. An ability-based view is not presented.

2.6.2 Whole system design

Whole systems design is one approach to sustainable design offering great potential, however the processes, principles, and methods guiding the whole systems approach are not clearly defined or understood by practicing designers or design educators (Charnley et al., 2011).

Evans (2009) describes whilst it is important to address the impact of each aspect of the industrial system and pursue aggressive reduction in the impact of specific activities, we must also examine the operation of the whole system. Efficiently manufacturing products that are inefficient in use, for example, is not enough. This approach can even result in substantially negative outcomes when efficiency gains or cost reductions result in increases in consumption (the so-called Rebound Effect). The

greatest opportunity to reduce the impact of the industrial system on the planet arises when we consider the whole system. The optimisation of any individual component of the industrial system.

Rocky Mountain Institute-RMI (2006) define whole system design as *'optimising not just parts but the entire system ... it takes ingenuity, intuition, and teamwork. Everything must be considered simultaneously and analysed to reveal mutually advantageous interactions (synergies) as well as undesirable ones'*. Whole-systems thinkers see wholes instead of parts, interrelationships and patterns, rather than individual things and static snapshots. They seek solutions that simultaneously address multiple problems (Anarow et al., 2003). Lovins (2011) are among the small number of authors who suggest that understanding the dynamics of a system is integral to the whole system approach. The Rocky Mountain Institute (2004) highlights systems thinking as the method that should be utilised not only to point the way to solutions to particular resource problems, but also to reveal interconnections between problems, which often permits one solution to be leveraged to create many more. Meadows (1997) lists nine places to intervene in a system, in increasing order of impact: numbers (subsidies, taxes, standards), material stocks and flows, regulating negative feedback loops, driving positive feedback loops, information flows, the rules of the system (incentives, punishment, constraints), the power of self-organisation, the goals of the system, and the mindset or paradigm out of which the goals, rules, and feedback structures arise.

It is suggested by the authors that reframing the system with a whole systems view helps people to understand more fully the way manufacturing affects the world we live in and how we might begin to change it (i.e. redesign the industrial system). Understanding who is involved in the current system and how they interact with it can help identify more opportunities to create sustainable value. The field of whole systems design and the literature surrounding it remains limited (Coley, 2009). Evans (2009) describes the evidence from the case studies implementing and shifting towards more sustainable manufacturing and demonstrates that dramatic improvements can be made at the level of sub-systems, such as factories or businesses. In parallel, however, it will be necessary to develop the understanding and

capabilities necessary to enable changes in the whole industrial system. Anarow et al. (2003) state that *"sustainability cannot be achieved in the absence of whole-systems thinking",* an ability that appears to be essential to improve industrial sustainability performance. There is lack of evidence and understanding of what abilities do companies need to improve their industrial sustainability at systems level. An ability-based view is not presented.

2.6.3 Systems innovation

It is argued the innovations required for sustainable development need to move beyond incremental adjustments. Sustainable development requires the transformation of larger parts of production and consumption systems (Boons, 2009). Incremental (product- and process-related) innovations in existing production and consumption systems may lead to further gradual improvements of sustainability performance, but in the end, incremental innovation frequently does not lead to a globally optimal system configuration in a multi-dimensional production and consumption system space (Wagner, 2011; Larson, 2000; Frenken et al., 2007; Vezzoli. et al. 2008; Schaltegger and Wagner, 2011).

While the term sustainable innovation has been widely used during the last decade, the number of definitions in the academic literature is limited (Holmes and Smart 2009; Boons and Lüdeke-Freund, 2013). The review by Carrillo-Hermosilla et al. (2010) lists innovation definitions that focus on ecological sustainability, such as eco-innovation and environmental innovation. For instance, Carrillo-Hermosilla et al. (2010) introduced their own definition of eco-innovation: *"innovation that improves environmental performance*". Charter et al. (2008) describes that given the challenges posed by sustainable development, sustainable innovation will often be characterised by systemness and radicalness. Generally, sustainable innovations go beyond regular product and process innovations and are future-oriented. Sustainable innovation goes beyond eco-innovation because it includes social objectives and is more clearly linked to the holistic and long-term process of sustainable development for the short- and long-term objectives of sustainability. Holmes and Smart (2009) describe the need for more research in sustainability-led innovations and partnerships.

Adams et al. (2016) presents a model of (SOI) sustainability-oriented innovation onto which sustainability oriented innovation practices and processes can be mapped:

- **Operational optimisation** (*e.g. eco-efficiency- compliance, efficiency, doing the same things better)*
- **Organisationtinal transformation** (*e.g. new market opportunities – novel products, services or business models, doing good by doing new things)*
- **Systems building** (*e.g. societal change- novel products, services or business models that are impossible to achieve alone, doing good by doing new things with others).*

Adams et al. (2016) describe sustainability-oriented innovation as making intentional changes to an organisation's philosophy and values, as well as to its products, processes or practices to serve the specific purpose of creating and realising social and environmental value in addition to economic returns.

Draper (2015) in the report- 'Creating the big shift: system innovation for sustainability, defines systems innovation as "*a set of actions that shift a system – a city, a sector, an economy – onto a more sustainable path"*. It is described in this definition; being able to identify the set of actions is important, systems change usually requires multiple interventions across different areas of society, it is very rare that a single person or innovation can change a whole complex system, such as waste or energy and tackling problems that are too large for any one organisation, however powerful, to solve on its own (e.g. shift systems to make them more resilient, more equitable and able to continue into the future). Draper (2015) states that there is an "*absence of necessary skills in sectors that can take the innovation to scale"*.

Sustainable development is argued by some authors to require radical and systemic innovations. Some authors argue these innovations can be more effectively created when building on the concept of business models. Sustainable business models provide the conceptual link between sustainable innovation and economic performance at higher system levels (Boons et al., 2013). Sustainable innovation is described by some authors to often be characterised by radicalness, some argue sustainable innovations go beyond regular product and process innovations and are

future-oriented (Charter et al., 2008). Sustainable innovation is described by Charter et al. (2008) "*Sustainable innovation is a process where sustainability considerations (environmental, social, and financial) are integrated into company systems from idea generation through to research and development (R&D) and commercialisation. This applies to products, services and technologies, as well as to new business and organisational models*". OECD (2012) state that *"we currently lack sufficient theoretical and practical knowledge to move towards sustainable systems of production and consumption. While there is a considerable amount of knowledge on what drives sustainable innovation at the firm level, we know less about how sustainable innovations can be realised and how win-win business situations can be created for those involved, while actually enabling sustainability at the level of production and consumption systems".*

2.6.4 Researchers' view – systems thinking, whole system design and systems innovations

It appears there is a need for organisations to develop the abilities to rethink the entire industrial system (understand what a system is and where the system boundary should be drawn). The systems thinking techniques are suggested to help organisations understand where they fit into the overall for example flow of materials and resources in their particular manufacturing process – and this understanding will help organisations recognise where the opportunity is to engage and intervene in the system to improve resource efficiency and create new forms of value. It is understood that there are multiple factors that influence the success of a whole system design process; identification of relationships between parts of a system to ultimately optimise the whole, and the need for actors involved in the process to develop trans-disciplinary skills and the dynamics of a flattened hierarchy, ability to think holistically and to view the bigger picture is suggested to be important. Senges' (2008) observations and research come the closest to this research in providing understanding of systems thinking being an essential ability for a learning organisation to move towards a sustainable industrial system. There is a lack in understanding of what systems-level abilities are needed for organisations to find opportunities for radical resource efficiency and value creation. Being able to set and expand the system boundaries, being able to identify points of intervention appears to

be important. An ability-based view is not directly presented.

Authors in the literature reviewed do not present an ability-based view or use that word. The researcher reviewed the literature through the lens of what abilities do companies need to improve their industrial sustainability at systems level and has been able to identify some high level abilities from the descriptions in the literature. In this section of the literature reviewed, the researcher has identified some important abilities:

Abilities	**Reference**
- Being able to take a long-term view and find opportunities to take advantage of	(Senge, 2008)
- Being able to understand the relationship between the industry and ecosystems	(Anarow et al., 2003)
- Being able to redesign the industrial system	(Rocky Mountain Institute-RMI, 2006; Hawken et al., 1999; Charter et al., 2008)
- Being able to find new business collaborators	(Senge, 2008; Adams et al., 2016)
- Being able to find opportunity for radical resource efficiency at system-level	(Schaltegger and Wagner, 2011)
- Being able to find advantageous interactions	(Meadows and Wright, 2009; Madrazo and Senge, 2011)
- Being able to see the bigger picture	(Senge, 2008)

Table 4. Abilities for improving industrial sustainability at systems level

2.7 Sustaining learning, sustainability competencies and abilities

Sustaining learning is a sub-theme of the learning literature, some of that literature seems to be useful in understanding competence and abilities for long-term e.g. sustainability change. In this section the researcher will bring out authors that have been identified as relevant and having insight into industrial sustainability abilities. There is a variety of terminological ambiguity; authors have associated the term competencies with abilities, capabilities, roles, experiences and other concepts (Barth et al., 2007; Wesselink et al., 2015). The above terms have been used interchangeably in the literature reviewed which is discussed in this section.

Recently in the last decade, there has been interest in conceptualizing key competencies in sustainability (Byrne, 2000; Barth et al., 2007; Sipos et al., 2008; Segalas et al., 2009; De Haan, 2010; Willard et al., 2010; Wiek et al., 2011; Wesselink et al., 2015). Dentoni et al. (2012) proposes a framework consisting of seven competencies required for professionals who are actively involved in dealing with sustainability in their work environment;

- **Systems thinking competence:** the ability to identify and analyse all relevant sub-systems across different domains (people, planet, profit) and disciplines, including their boundaries. Systems thinking competence is the ability to understand and reflect upon the interdependency of these sub-systems, including cascading effects, inertia, feedback loops and accompanying cultures (Wiek et al., 2011).
- **Embracing diversity and inter disciplinarily competence:** the ability to structure relationships, spot issues, and recognise the legitimacy of other viewpoints in business decision making processes; be it about environmental, social and/or economic issues. It is the ability to involve all stakeholders and to maximise the exchange of ideas and learning across different groups (inside and outside the organisation) and different disciplines (De Haan, 2010; Ellis and Weekes, 2008; Wilson et al., 2006).
- **Foresight thinking competence:** the ability to collectively analyse, evaluate, and craft pictures of the future in which the impact of local and/or short term decisions on environmental, social and economic issues is viewed on a global/cosmopolitan

scale and in the long term (Wiek et al., 2011).

- **Normative competence:** the ability to map, apply and reconcile sustainability values, principles and targets (Wiek et al., 2011).
- **Action competence:** the ability to actively involve oneself in responsible actions for the improvement of the sustainability of social-ecological systems (De Haan, 2010; Mogensen and Schnack, 2010).
- **Interpersonal competence:** the ability to motivate, enable and facilitate collaborative and participatory sustainability activities and research (Wiek et al., 2011).
- **Strategic management competence:** the ability to collectively design projects, implement interventions, transitions, and strategies for sustainable development practices. This domain involves skills in planning (e.g., design and implement interventions), organising (arranging tasks, people and other resources), leadership (inspiring and motivating people) and control (e.g., evaluating policies, programmes and action plans) (De Haan, 2010; Wiek et al., 2011).

Rieckmann (2012) conducted a Delphi study with 70 ESD (Education for Sustainable Development) experts from Europe and Latin America and formulated 19 key competences for ESD: systemic thinking and handling of complexity, anticipatory thinking, critical thinking, acting responsibly, recognising and analysing problems of unsustainable development, cooperation in (heterogeneous) groups, participation, empathy and change of perspective, open-mindedness and disposition to innovations, interdisciplinary work, recognizing one's own role in the global community, concern and acting for justice, handling of intercultural relationships, understanding of nature, handling of information, communication and use of media, planning and realising projects, evaluation, ambiguity and frustration tolerance. System thinking, anticipatory thinking, and critical thinking were deemed by these experts to be the most important competencies.

There is growing social pressure on companies to consider 'people, planet and profit'. It is suggested that sustainable leaders seek to balance short-term and long-term priorities and create value for a variety of stakeholders (Galpin et al., 2012). Senge et al. (2008) in the book '*The Necessary Revolution: How Individuals and Organisations*

are Working Together to Create a Sustainable World', highlight what some of the major sustainability problems are; and how some leaders are making positive change and why that makes good business sense. It is stated that sustainability issues are interconnected. Senge et al. (2008) states that institutions must work together. It is suggested leaders must look beyond immediate, short-term gains to see the role of the organisation in a larger context (i.e. being able to see the bigger picture).

In his book The Fifth Discipline, Senge (1990) defined a learning organisation as *"... a place where people continually expand their capacity to create results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free and where people are continually learning how to learn*". Senge (2006) described the core of a learning organisation's work as based upon five learning disciplines, which represented lifelong programs of both personal and organisational learning and practice.

These include:

- ***Personal mastery:*** individuals learn to expand their own personal capacity to create results that they most desire. Employees also create an organisational environment that encourages all fellow employees to develop themselves towards the goals and purposes that they desire. It is suggested aspiration involves formulating a coherent picture of the results people most desire to gain as individuals (their personal vision), alongside a realistic assessment of the current state of their lives today (their current reality). Learning to cultivate the tension between vision and reality can expand people's capacity to make better choices, and to achieve more of the results that they have chosen.

- ***Mental models:*** this involves each individual reflecting upon, continually clarifying, and improving his or her internal pictures of the world, and seeing how they shape personal actions and decisions. It is suggested reflection and inquiry skills is focused around developing awareness of the attitudes and perceptions that influence thought and interaction. By continually reflecting upon, talking about, and reconsidering these internal pictures of the world, people can gain more capability in governing their actions and decisions.

- ***Shared vision:*** this involves individuals building a sense of commitment within particular workgroup, developing shared images of common and desirable futures, and the principles and guiding practices to support the journey to such futures. It is suggested that collective establishes a focus on mutual purpose. People learn to nourish a sense of commitment in a group or organisation by developing shared images of the future they seek to create, and the principles and guiding practices by which they hope to get there.

- ***Team learning*****:** this involves relevant thinking skills that enable groups of people to develop intelligence and an ability that is greater than the sum of individual members' talents. It is suggested that in a group through techniques like dialogue and skillful discussion, teams transform their collective thinking, learning to mobilize their energies and ability greater than the sum of individual members‘ talents.

- ***Systems thinking:*** this involves a way of thinking about, and a language for describing and understanding forces and interrelationships that shape the behaviour of systems. This discipline helps managers and employees alike to see how to change systems more effectively, and to act more in tune with the larger processes of the natural and economic world. It is suggested people learn to better understand interdependency and change, and thereby to deal more effectively with the forces that shape the consequences of our actions. Systems thinking is based upon a growing body of theory about the behavior of feedback and complexity-the innate tendencies of a system that lead to growth or stability over time. Tools and techniques such as systems archetypes and various types of learning labs and simulations help people see how to change systems more effectively, and how to act more in tune with the larger processes of the natural and economic world.

Senge (2008) proposes three core-learning capabilities; seeing systems, collaborating across boundaries and creating desired futures for systemic change (Figure 4).

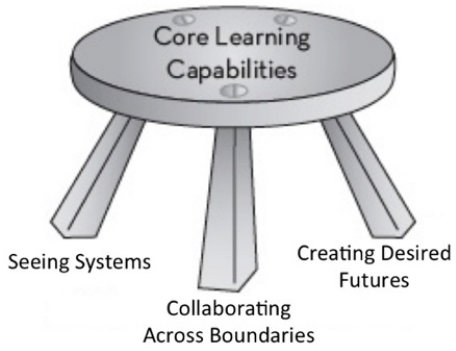


Figure 4. Core-learning capabilities – (Senge, 2008)

Senge (2008) states that these capabilities are needed for creating regenerative organisations, industries and economies and states that if you take away one the whole fails. The researcher agrees with this view that without the capacity to see systems and their place in them, people and organisations will naturally focus on optimising their piece of the puzzle rather than building shared understanding and a larger vision. The framework highlights the capability of seeing system being important in a world of growing interdependence, it appears organisations failing to do so leads to policies and strategies whose side effects eventually damage the intended effects. The author highlight many regenerative resources, such as water, topsoil, and fish stocks, are declining because businesses and communities follow strategies of maximizing short-term production without stepping back to look at the larger system and see whether they're consuming resources more rapidly than they are being replenished. (Madrazo, 2011) using case study examples highlights, organisations that fail to develop these abilities tend to react to growing problems with shorter-term fixes more within their control. (Madrazo, 2011) using case study examples highlight many companies react to water shortages for example by simply moving to different countries with laxer government regulations, and these organisations before long are found spending more and more money on lobbying and burnishing their image, while underlying problems grow.

2.7.2 Ability vs. competence

This section provides a summary of definitions from resource-based view on competencies, abilities and capabilities and then offers other definitions from other management domains. There is a variety of terminological ambiguity and the above terms have been used interchangeably in the literature reviewed which is discussed.

Resource-based view (RBV) key themes and definitions

In the resource-based view (RBV) resources are broadly understood as any assets that an organisation might draw upon to **help achieve its goals or perform well** on its critical success factors (Barney, 1991). It concerns itself with resources as being critical to a firm's competitive advantage and long-term survival (Schumpeter, 1942). Whilst importance is attached to all physical and organisational resources, special reference is made to **knowledge and competencies based resources** (Bryson et al., 2007; Barrutia et al., 2015). RBV emphasises the **importance of resources for organisational survival, growth, and overall effectiveness** (Barney 1991; Wernerfelt, 1984) and focuses on scarce, valuable, and imperfectly imitable resources as factors for creating sustained performance differences among competing firms. The RBV primarily adopted an inward looking approach by assuming that complete control or ownership of resources is necessary to achieve competitive advantage (Wernerfelt, 1984). More recent studies have recognised the importance of resources stemming from dyadic relationships with partners and from network structures, which represent relational resources, and their influence on organisational outcomes (Arya and Lin, 2007; Lavie, 2006). The relational view (Dyer and Singh, 1998), in particular, emphasises common resources that alliance partners cannot generate independently. It is described "*the focus of the RBV is not only on how to squeeze innovative output out of the organisations, but also on how to provide the fuel for innovative activity to occur in the first place" (Kostopoulos et al., 2002).*

- **Resources** are the inputs or the factors available to a company, which **helps to perform its operations or carry out its activities**. Resources include basic resources and higher-order resources (Madhavaram and Hunt, 2008). Higher-order resources are understood as bundles of basic resources and are made up of combinations of tangible and intangible basic resources that fit together coherently

in a synergistic manner to enable organisations to meet their goals. They are usually referred to as **competences and/or capabilities**.

- **Competences and capabilities** connote a **subset of resources** and **consist of abilities, sets of actions**, technologies, or processes that help an organisation perform well against important goals or critical success factors (Bryson et al., 2007).
- Makadok (2001) emphasises the **distinction between capabilities and resources** by defining **capabilities** as "*a special type of resource, specifically an organisationally embedded non-transferable firm-specific resource whose purpose is to improve the productivity of the other resources possessed by the firm"*.
- **Dynamic capabilities** refer to the firm's ability to integrate, build, and reconfigure internal and external **competences** to address rapidly changing environments (Teece et al., 1997)
- The presence of the **ability enables** capability to be performed along the entrepreneur's vision or strategy, capability enables resources to begin to be utilized, and the potential for the creation of service arises (Tokuda, 2005).

The RBV literature contributes to understanding the importance of resources in helping a company perform its operations or carry out its activities. The literature provides understanding that competences and capabilities are a **subset of resources and consists of abilities.** From the resource-based view perspective it is suggested that innovation does not come simply from scanning the external environment for market opportunities, but from looking inside and building on the resource endowment and core competencies of the organisation. Organisational resources and capabilities are taken to offer the necessary input for the development and exploitation of the firm's innovation activities.

Other management key themes and definitions

There are many more definitions in the literature on competencies, abilities and capabilities, depending on the perspective of the author and the unit of analysis of the study. In order to fully understand what is meant by competence and ability in this research, the researcher uses the following definitions to define the concept. Authors

have linked the term '**competencies**' with **abilities**, capabilities and roles (Barth et al., 2007). "*The study of the concepts of **abilities** and **skills** involves the consideration that both items belong, along with the knowledge, to the **broader field of competence***" (Manzanera-Román et al., 2016). Regarding the concept of **competence** and its definition, there have been a multitude of approaches. The first approach may be attributed to McClelland (1973), who posed **competence as anything that allows improved performance of a task.** Boyatzis (1982) defined competences as "*characteristics underlying the person who can relate to their skills, traits or a set of knowledge*". Spencer et al. (1993) considered latent personal characteristics that allow the effective exercise of a task.

- **Competencies in sustainability**: complexes of knowledge, skills, and attitudes that enable successful task performance and problem solving with respect to real-world sustainability problems, challenges, and opportunities (Barth et al., 2007).
- **Competence: ability to** apply knowledge, skills and personal qualities to be successful in a particular area (Berkimbaev et al., 2012)
- **Ability**: particular elements of an individual's personality that allow the execution of tasks and determine the successful development of such a task or activity**.** (Manzanera-Román et al., 2016).

In both the RBV literature and other management literature, the term ability is suggested to be one of the elements that make up the competence/capability.

In education, as well as in the corporate world, the term competency is used as a vehicle for communicating about performance and learning processes of individuals (Mulder, 2012). Boyatzis (1982) and McLagan (1989) were the first to link the practice of human resource management to development in organisations. Competencies are seen as useful (e.g., Dubois and Rothwell, 2004; Lievens et al., 2004), since they can be utilised in strategic workforce planning, selection, training and development, performance management, succession planning, and motivation and rewarding. Using competencies in organisations has benefits for both organisation and employee. The former is able to align its strategic goals with the goals of the employees, and the latter experiences more transparency (Mulder, 2012). Nonetheless, the concept of competence has been applied in widely differing ways in

different countries (Gonczi, 1994), in different disciplines, and at different times. It is this widespread use that is one of the major pitfalls in working with competencies (Biemans, Nieuwenhuis, Poell, Mulder and Wesselink, 2004; Wesselink et al., 2015).

One can distinguish three main conceptualisations of competence: behaviouristic, generic and holistic (Biemans et al., 2004). In the behaviouristic conceptualisation competencies are described as observable behaviours (no attention is paid to the individuals' input, only the output is studied) associated with the completion of each small task (Gonczi, 1994). In the generic conceptualisation of competence, which was formulated as a response to the behaviouristic approach, competencies are personal qualities (character traits included) that distinguish average performers from excellent performers (Eraut, 1994). Biemans et al. (2004) indicate that most interpretations of competencies are derived from the holistic conceptualisation. Within the holistic tradition, the concept of competence is defined as follows: *"Competence is the integrated performance oriented capability of a person or an organisation to reach specific achievements. These capabilities consist of clusters of knowledge structures and also cognitive, interactive, affective and where necessary psycho-motoric skills, and attitudes and values, which are conditional for carrying out tasks, solving problems and effectively functioning in a certain profession, organisation, position and role"* (Mulder, 2014). Hodkinson and Issitt (1995) distinguish two dimensions of holism. The first dimension concerns the integration of knowledge, skills and attitudes that are meaningful to someone who is (becoming) a practitioner. The second dimension of holism relates to the inter- relatedness with the context; competencies can only be displayed in a context by taking core tasks or roles into account.

Weinert (2001) argues that competencies may be characterised as individual dispositions to self-organisation, which include cognitive, affective, volitional and motivational elements; they are an interplay of knowledge, capacities and skills, motives and affective dispositions. Consequently, these components are part of each competency, not having to be regarded independently, but in their interaction. While competency is considered as the precondition for self-organised action, the notion of performance means the execution of the action itself.

2.7.3 Researchers' view ability vs. competence

Over the last few years, numerous articles and reports have made significant progress in conceptualising key competencies in sustainability (Byrne 2000; De Haan 2010; Barth et al., 2007; Sipos et al., 2008; Segalas et al., 2009; Willard et al., 2010; Wiek et al., 2011; Rieckmann, 2012; Osagie et al., 2014; Wesselink et al., 2015). Hesselbarth and Schaltegger (2014) state that *"empirical findings about what is required of the sustainability professionals are still limited"*. These authors don't take an ability-based view, but most present a competency-based view that lacks in case evidence. Senge (2008) describes the need for understanding abilities to develop learning organisations. Authors don't talk about a wide range of abilities that might be needed to transform from todays position towards a sustainable industrial system.

There is a variety of terminological ambiguity; authors have associated the term competencies with abilities, capabilities, roles, experiences and other concepts (Barth et al., 2007; Wiek et al., 2011; Wesselink et al., 2015). The above terms have been used interchangeably in the literature reviewed which is discussed. In both the RBV literature and other management literature, the term ability is suggested to be one of the elements that make up the competence/capability**.** The researcher has decided to use the term ability to explore and gain deeper insights on the specific abilities needed by companies to improve their industrial sustainability. The research will use a variety of literature to inform this research. The researcher has been able to pick up 1 or 2 things that might be interesting in the future. There is a lack of case evidence and understanding on what abilities do companies need to improve their industrial sustainability (i.e. abilities needed).

Much of the literature is unclear in distinguishing between **individual level** and **organisational/system level** competencies. Authors such as (Dentoni et al., 2012; Barth et al., 2007; Wiek et al., 2011; Wesselink et al., 2015) for example propose **competencies required for professionals** who are actively involved in dealing with sustainability in their work environment (i.e. individual level competencies). Though the authors refer to the competencies they propose as individuals level competencies, some of the competencies proposed are described at the level of the organisation. For example, **foresight thinking** (the ability to collectively analyse, evaluate, and craft

pictures of the future in which the impact of local and/or short term decisions on environmental, social and economic issues is viewed on a global/cosmopolitan scale and in the long term (Wiek et al., 2011; Dentoni et al., 2012)) & **systems thinking competence (**the ability to identify and analyse all relevant sub-systems across different domains (people, planet, profit) and disciplines, including their boundaries. Systems thinking competence is the ability to understand and reflect upon the interdependency of these sub-systems, including cascading effects, inertia, feedback loops and accompanying cultures (Wiek et al., 2011)). These can only be described as organisational level competencies. Senge (2008) on the other hand describes system thinking as an organisational level capability required to develop a learning organisation. The literature on capabilities have used a variety of different definitions and different levels of scope, including both individual level and organisational level. The author suggests that this results in considerable confusion and poor integration of the literature.

2.8 Research Gap

The researcher has reviewed in total 412 journal papers and books. The authors that are relevant and that come closest to providing understanding to the research problem are described in the literature review. The researcher has investigated the industrial sustainability concepts to see what it tells about industrial sustainability. The researcher has investigated specific elements of industrial sustainability implementation, and the research has looked at the particular difficulty of defining ability. Senge (2008) describes the need for understanding abilities needed to develop learning organisations and improving industrial sustainability. Although the researcher has looked at a lot of literature about frameworks, resource efficiency, sustainable business models, systems, abilities and competencies. The authors don't take an ability-based view. The researcher is yet to find a paper that is directly about a wide range of abilities that might be needed to transform from todays position towards a sustainable industrial system (i.e. literature providing an understanding of abilities with supporting case evidence is rare).

2.8.1 The confirmed research question

Gaps in current knowledge and understanding highlighted above confirm that the research question remains novel;

- What abilities do companies need to improve their industrial sustainability?

Sub-questions

- What are companies doing to improve industrial sustainability?
- How are they doing it?

The research question is based on the literature reviewed and addresses the gap in existing knowledge. The research question will be answered in this study by undertaking the research in two stages of collecting and analysing data. The first stage is exploratory which will inform the descriptive stage.

2.9 Chapter Summary

This chapter presented the existing know-how and contributions and discussions by pioneering authors in the field from different research domains. It appears there is extensive literature on system change and sustainability mental models but little evidence and understanding is found on what do companies need to be good at to improve their industrial sustainability performance. The chapter confirms the research gap and presents the research question.

Chapter 3

Research design

This chapter presents research methodological alternatives considered and reasons for the selection made.

3.1 Introduction

This chapter presents the range of research methods considered and the decisions made by the researcher to develop an appropriate and rigorous approach to carrying out research. The first section presents the research philosophy, perspective (deductive vs. inductive), purpose (exploratory, descriptive or explanatory), and type of research (qualitative, quantitative). Then data collection methods and analysis techniques are discussed and the selected methods described, finally a model of the research design is presented. The research seeks to better understand what abilities do companies need to improve their industrial sustainability.

3.2 Positivism versus phenomenology

There are two major and opposing perspectives towards research into social enquiry (i.e. positivism & phenomenology). Each provides different views of what social reality is and how it should be uncovered from its natural setting. Both the phenomenological (inductive approach) and positivistic (deductive approach) research perspectives were considered;

- Crowther and Lancaster (2008) state that positivist research usually adopts a deductive approach. A deductive approach requires the development of a hypothesis based on existing theory, and then designing a research strategy to test the hypothesis (Lemon, 2002; Blaikie, 2000). Deductive research usually explores a known theory or phenomenon and tests if that theory is valid in a given set of circumstances.

- Easterby-Smith et al. (2002) state that phenomenologist research is often linked to inductive research. Inductive research is described as the reverse of deductive, as it involves moving from observation of the empirical world to the construction of explanations and theory on the basis of what has been observed (Gill & Johnson, 2002). The approach seeks to understand the phenomena by 'getting inside situations' and understanding them within their real life context.

	Positivism	Phenomenology
Basic notions	- The world is perceived as external and objective - Independency of the observer - Value-free approach to science	- The world is perceived to be socially constructed and subjective - Observer is considered a part of the object of observation - Human interests drives science
Responsibilities of researcher	- Focusing on facts - Causalities and fundamental laws are searched - Phenomenon are reduced to the simplest elements - Hypotheses formulation and testing them	- To be focusing on meanings - Aiming to understand the meaning of events - Exploring the totality of each individual case - Ideas are developed by induction from data
Most suitable research methods	- Concepts have to be operationalised	- Using several methods in order to different aspects of phenomena
Sampling	- Samples have to be large	- Small samples are analysed in a greater depth or over longer period of time

Table 5. Positivist and phenomenology paradigms (Easterby-Smith et al., 2002)

Applicability to this research and choice made:

This research seeks to better understand ‘what abilities do companies need to improve their industrial sustainability?’ There is lack of understanding and research in this subject area (e.g. ability to improve non-labor productivity) and no claimed theories. Poor understanding and a lack of useful theories make it challenging to deduce propositions for testing. Therefore positivist research philosophy is unlikely to reveal new knowledge in this research. This knowledge needs to be generated by collecting evidence and then seeking to find some patterns in evidence. This research will build on specific observations to offer broader generalizations and theories.

A **phenomenological perspective and inductive research approach is chosen to be the most appropriate.** This approach seeks to understand the subject through the subjective viewpoint of people involved in the process (i.e. manufacturing companies improving industrial sustainability performance).

3.3 Determining the research data type (qualitative, quantitative)

The social science research approach is generally either quantitative or qualitative;

Quantitative research typically assumes that everything in the social world can be described or measured with a numerical system (McQueen and Knussen, 2002). Quantitative data often relies on the random selection of a large and representative sample of people from which data can be collected in a standard, robust way so that an accurate view of the group can be produced and statistical analysis of the findings can be conducted. It deals with facts and figures and has many benefits due to its replicability and generalisability to other research settings and real-world circumstances (Robson, 2002; 2011).

Qualitative research is often based around social and behavioural studies in which specific outcomes cannot be expected, and so exact ways in which to measure data are undetermined (Robson, 2011). Some of the data may be quantified, but analysis itself is of a purely qualitative nature (Strauss & Corbin, 1990). One major feature of qualitative data is that it focuses upon ordinary events in natural settings, so a strong handle on 'real life' can be reached. The data generated has the strengths of being rich and holistic, with a strong potential for revealing complexity (Miles & Huberman, 1994). The distinctions between the two research types are summarised in table 6.

Qualitative research	Quantitative research
- Deals mainly with the exploration of issues and the generation of theories within new and emerging subject areas - Is used to develop insight and understanding of a subject - Seeks to create gestalt and holistic interpretations	- Is used in research that requires facts and figures in order to answer the research question (through verification of hypothesis) - Seeks to measure, test, and quantify elements in order to explain or describe something

Table 6. Qualitative and quantitative types of research (Robson, 2002).

Easterby-Smith et al. (2002) argue that quantitative research methods have often been focussed on describing, coding and counting events at the expense of understanding why things are happening. By contrast, qualitative methods might concentrate on exploring people's viewpoint in much deeper detail, or the reasons for, or consequences of, the choice of performance criteria. Rourke and Andersen (2004) for instance states that qualitative methods are often used to identify problem areas within an organisation. When studying organisational or human cases, qualitative methods such as interviews, observations and document analysis are commonly used to gain in-depth knowledge about the case(s) (Robson, 1993). Furthermore, there seems to be a tendency to use quantitative methods in deductive research where the emphasis is on testing theory, whereas qualitative methods seem to be used more frequently when the aim of the research is inductive e.g. focussing on the generation of theory (Bryman, 1994).

	Qualitative	Quantitative
Assumptions	- Reality socially constructed - Variables complex and interwoven; difficult to measure - Events viewed from informant's perspective - Dynamic quality to life	- Facts and data have an objective reality - Variables can be measured and identified - Events viewed from outsider's perspective - Static reality to life
Purpose	- Interpretation - Contextualisation - Understanding the perspectives of others	- Prediction - Generalisation - Casual explanation
Method	- Data collection using participant observation,	- Testing and measuring - Commences with hypothesis and

	unstructured interviews - Concludes with hypothesis and grounded theory - Emergence and portrayal - Inductive and naturalistic - Data analysis by themes from informants descriptions Data reported in language of informant - Descriptive write-up	theory - Manipulation and control - Deductive and experimental - Statistical analysis - Statistical reporting - Abstract impersonal write-up
Role of researcher	- Researcher as instrument - Personal involvement - Empathic understanding	- Researcher applies formal instruments - Detachment - Objective

Table 7. Qualitative and Quantitative Research Strategies (Burns, 2000)

Applicability to this research and choice made:

It has been shown that the selected philosophical orientation of the research is that of phenomenology, which traditionally advocates the use of qualitative methods for data gathering and analysis (Easterby & Smith, 2002).

The research question explored in this research is taken into account and determines the research method selected. Having compared both qualitative and quantitative approaches (table 7), it was decided that a qualitative approach would be the most appropriate method. The reasons for this choice are;

- The study involves observation & exploration of how companies improve their abilities.
- Identification and analysis of individuals and of their group behavior is needed.
- The type of data is unlikely to be quantified or quantifiable.

A qualitative approach will also provide the research with the flexibility to make changes within the research design as and when necessary. This research can therefore be classified as being qualitative, using methods such as interviews, observation and document analysis to seek in-depth understanding.

3.4 Research purpose (exploratory, descriptive, explanatory)

A phenomenological (inductive) approach was selected, which implies that the research will seek to generate new knowledge and insights based on observations.

Robson (1993) describes 3 categories that the research purpose can be categorised into in social science: exploratory, descriptive and explanatory (table 8).

Exploratory Aims to seek new insights, ask questions and find out what is happening	**Descriptive** Aims to provide an accurate profile of the situation or phenomenon being studied	**Explanatory** Aims to explain the phenomenon being studied, often in the form of causal relationships
- Key variables not defined - To find out what is happening - To seek new insights - To ask questions - To assess phenomena in a new light - Usually, but not necessarily, qualitative	- Key variables are defined - To portray an accurate profile of persons, events or situations - Requires extensive knowledge of the situation to be researched - Maybe qualitative and/or quantitative	- Key variables and key relationships are defined - Seeks an explanation of a situation or problem, usually in the form of causal relationships - May be qualitative and/or quantitative

Table 8. The purpose of the research adapted from (Robson, 1993).

Robson (1993) states that exploratory research can be useful in research where little is known, and which is characterised by poorly formulated ideas or hypotheses at the beginning of the study. The insight gathered from an exploratory stage is suggested to aid and form the foundation to conduct descriptive research. It is suggested that explanatory research could then be conducted to test the theories generated by the exploratory and descriptive research.

Applicability to this research and choice made:

The purpose of this research fits into the exploratory and descriptive categories. It is exploratory because the research first seeks to better understand what abilities do companies need to improve their industrial sustainability, which is lacking in prior theory and is therefore exploratory and seeking to find out what is happening. Therefore a decision is made to conduct the research in 2 stages. From the exploratory stage the research seeks to identify the specific abilities used by companies to improve their industrial sustainability. The exploratory stage will provide high-level understanding of these abilities that emerge. Based on the analysis and themes from the exploratory stage, new data will be collected in stage two to confirm, reject or add

detail to the themes identified. The second stage would be descriptive as the themes that emerge in the exploratory stage, the research seeks to provide an accurate description of observations of a phenomena. The research design will consist of an **exploratory and a descriptive** stage to answer the research question being investigated.

3.5 Data collection strategies

This section presents the research strategies case study or experimental that is considered and the reasoning for choosing the case study method.

➢ Case Study

A methodology for doing research that involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence (Robson, 1993; Yin, 1994). Case study is described to be an effective strategy for conducting exploratory research (Robson, 1993). Case study research is suggested as an appropriate empirical method to gain explorative, qualitative, real-life insight in order to build theory (Yin, 2009). This is done through a wide range of techniques including interview, observation and document analysis (Robson, 1993). Yin (2009) states case studies have been used in exploratory, descriptive and explanatory research.

Strengths

- Good method for exploring a field and generating hypotheses.
- Enables a researcher to gain deep insights of a particular phenomenon.
- Case studies are a commonly used and proven methodology within research that are exploratory.

Weaknesses

- Typically can only focus on a small number of cases in any single research study; hindering the generalisablity of results.
- Researchers may influence events and persons involved.

Choice made

✓ This method is chosen as;

- The actions and behaviour of people are central aspects within this research.
- A case study approach has been selected as the most appropriate research strategy for meeting the exploratory and descriptive goals of the research investigation.

➢ Quasi / Experimental

Measuring the effects of manipulating one variable on another (Gill & Johnson ,1997; Robson, 1993; Zikmund, 1991). Experiments are characterised by 'measuring the effects of manipulating one variable on another variable' (Robson, 1993). Experiments are commonly used to test theories through the support or falsification of hypotheses derived from the theory that is being tested. It is implied that the use of experiments require the variable of interest to be manipulated while other variables are carefully controlled.

Strengths

- Useful for establishing cause and effect relationships.

Weaknesses

- Realism and generalisability tend to be sacrificed.
- High level of understanding required to ensure the small number of variables being analysed are the most appropriate.

Choice made

This method is **not** chosen as;

- The researcher felt it would be almost impossible to apply this approach, due the amount of variables unknown likely to exist in this type of research.

3.6 Data collection techniques and analysis

A case study strategy is chosen, and within case study some techniques for data collection are considered. The research selected action research, focus groups, interviews and participant observation as more suitable data collection techniques for this research.

➢ Action Research

Action research is an established research method in the social sciences that can be traced back to 1940s when Kurt Lewin coined the term action research. Lewin (1946) argued that research for social practice should be concerned with the diagnosis of specific situations. Lewin (1946) suggests this method is of learning about organisations through trying to make change (i.e. active problem solver). It is described as one particular method that can be adopted when working with case study research (Gummesson, 2000). Action research is described to involve two goals: to

solve a problem and to contribute to science. Action research requires cooperation between the researcher and the company's personnel, feedback to the parties involved, and continuous adjustment to new information and new events as performed along the research. Action research is described as being a useful method to conduct research in understanding and planning of change in social systems (Easterby-Smith 2002).

Strengths

- Provides the researcher with substantially improved access to data.
- Recognises the difficulty of studying complex social events in a real-world setting.
- Attempts to 'learn by doing'.

Weaknesses

- Relies on close collaboration between the parties, which may cause researcher bias in the findings.
- Requires open access to rich data sources.

Choice made

✓ This method is chosen as;

- It is a useful method to adopt in organisation participating in trying to improve industrial sustainability performance.
- Intervention settings can provide rich data about what people do and say, and what theories are used and usable, when faced with a genuine need to take action.
- It will be a useful method in the descriptive stage of the research, to seek new data to confirm, reject or add detail to the themes identified in the exploratory stage.
- Each intervention provides an opportunity for the researcher to revisit theory in order to design the intervention and develop it further as a result (Deising, 1972). Action research is uniquely placed in developing theory that is of relevance to practice.

➢ Focus Groups

Focus groups can attain information from people with different perspectives about a problem; furthermore, they can provide an overall appreciation of a problem that rarely emerges from other data collection methods like individual interviews or surveys (Van de Ven, 2007).

Strengths

- Effective technique for idea generation.
- Focus groups can attain information from people with different perspectives about a problem; furthermore, they can provide an overall appreciation of a problem that rarely emerges from other data collection methods like individual interviews or surveys (Van de Ven, 2007).
- Multiple views brings richness to the data.
- Participants reflect on what other people say providing the research their reactions to data – which is very revealing.
- Respondents can feel secure in the environment.

Weaknesses

- Dominant participants can distort findings.
- Dependent on an effective moderator.
- People can be less willing to share sensitive information within a group setting.

Choice made

✓ This method is chosen as;

- Due to the exploratory nature of focus groups, they provide an excellent technique for identifying potential important facts within a group environment. Wide range of insights and ideas can be gained. Interesting insights can be collected when participants both query each other and explain themselves to each other.
- The research will use focus groups, which will be organised in the form of industry workshops with the participation of senior level managers and academic experts interested in improving non-labor productivity and improving industrial sustainability performance to gain insights on the research question explored.
- Focus groups will allow respondents to be given more freedom to comment on what they perceived to be important within a predefined area, with the researcher taking a less directive role than with standard interview techniques.

➢ Survey

The collection of information in a standardised form from groups of people (Gill & Johnson, 2002; Robson, 1993; Zikmund, 1991). Surveys are used to collect information in a standardised form, usually in the format of questionnaires or structured interviews (Robson, 1993). The standardised format of surveys provides data that are easily transformed into quantitative or statistical representations.

Strengths

- Typically highly generalisable from the sample surveyed to the whole population.
- Quick, inexpensive and accurate means of assessing the population.
- Extremely efficient at providing large amounts of data.

Weaknesses

- Approach is prone to sampling errors.
- Poor response rates.
- Typically low response rates where responses can be falsified or misrepresented.
- Ambiguities in the survey questions may not be detected.

Choice made

✗ This method is **not** chosen as;

- The research is exploratory in nature and this method relies on identified variables, which does not yet exist.
- The development of a structured and robust questionnaire would be extremely difficult due to the lack of theoretical propositions surrounding the subject and exploratory nature of the research.

➢ Interviews

Interviews give the researcher the opportunity to probe deeply and uncover new clues, understanding new dimensions of a problem, through the acquisition of data based on an individual's personal experience (Easterby-Smith, 2002).

Strengths

- Targeted: focused directly on the case study topic.
- Insightful: Provides perceived causal inferences.

Weaknesses

- Bias due to poorly constructed questions.
- Response bias.
- Inaccuracies due to poor recall.
- Reflexivity- interviewee gives what interviewer wants to hear.

Choice made

✓ This method is chosen as;

- A semi-structured interview technique will be best suited for this research, as it gives the needed guidance to ensure a sufficient coverage of the topic as well as allowing the researcher (interviewee) to take the conversation in a direction where the topic of investigation made sense to the individual.
- Interviews can be used in both the exploratory and the descriptive stages of the research.
- A semi-structured interview format will be pursed.

➢ Participant observations

Participant observation provides the ability to perceive reality from the viewpoint of someone inside the case study rather than external to it (Yin, 1994; 2009). Participant observation will record cause and effect relationship real-time with context of the event (Yin, 2009). Through participant observation, it is possible to describe what goes on, who or what is involved, when and where things happen, how they occur, and why at least from the standpoint of participants.

Strengths

- Reality: covers information in the real time.
- Contextual: covers context of the event.
- Insightful into personal behaviours and motives.

Weaknesses

- Time consuming.
- Selectivity: unless broad coverage.
- Reflexivity: event may proceed differently because it is being observed.
- Cost: hours needed by human observation.

Choice made

✓ This method is chosen as;

- Observational evidence is often useful in providing additional information about the researched topic (Yin, 2009).
- Observations from the company site can provide better understanding and rich information about the subject.
- Participant observation is described to be especially appropriate when little is known about the phenomenon.

➢ Thematic coding

Thematic analysis is a common form of analysis in qualitative research (Miles and Huberman, 1994). Thematic analysis is a method for identifying, analysing and reporting patterns (themes) within data (Braun and Clarke, 2006). Themes are patterns across data sets that are important to the description of a phenomenon and are associated to a specific research question. Braun and Clarke (2006) describe that researchers interested in looking for broader patterns in order to then conduct a more fine grained analysis often use thematic analysis. Braun and Clarke (2006) provide a guide for conducting thematic analysis:

- **Familiarising yourself with your data:** Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.

- **Generating initial codes:** Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
- **Searching for themes:** Collating codes into potential themes, gathering all data relevant to each potential theme.
- **Reviewing themes:** Checking if the themes work in relation to the coded extracts (phase 1) and the entire data set (phase 2), generating a thematic 'map' of the analysis.
- **Defining and naming themes:** Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
- **Producing the report:** The final opportunity for analysis. Selection of vivid compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Strengths

- Well suited to large qualitative data sets.
- Interpretation of themes supported by data.
- Allows for categories to emerge from data.
- Thematic analysis is a flexible approach that can be used across a range of epistemologies and research questions.

Weaknesses

- Researcher judgment is needed to determine what a theme is.

Choice made

✓ This method is chosen as;

- Useful in capturing patterned response or meaning within the data set (Braun and Clarke, 2006).
- Braun and Clarke (2006) describes that a rigorous thematic approach can produce an insightful analysis that answers particular research questions.
- As the research has adopted an inductive approach, thematic analysis has been chosen to represent this as patterns and themes can be identified from the raw data.
- Using this method the data can be analysed without being simplified, allowing the underlying complexity to remain accessible.

Figure 5 illustrates a summary of the high level choices made in this section. The diagram presents the philosophical, research type, research purpose, research strategy and data collection and analysis choices made. The detailed research plan will be presented in the next section.

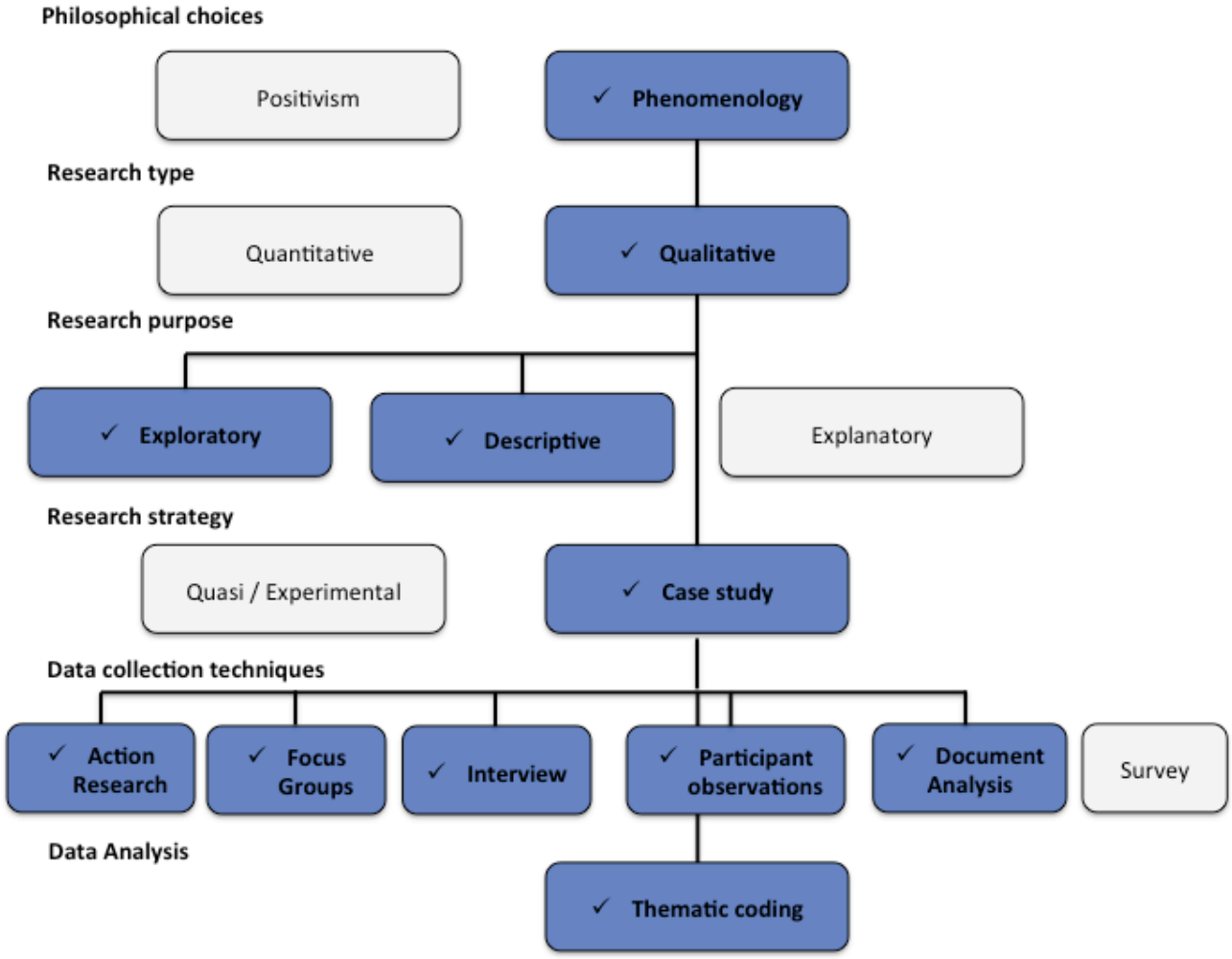


Figure 5. Philosophical and research strategy choices made

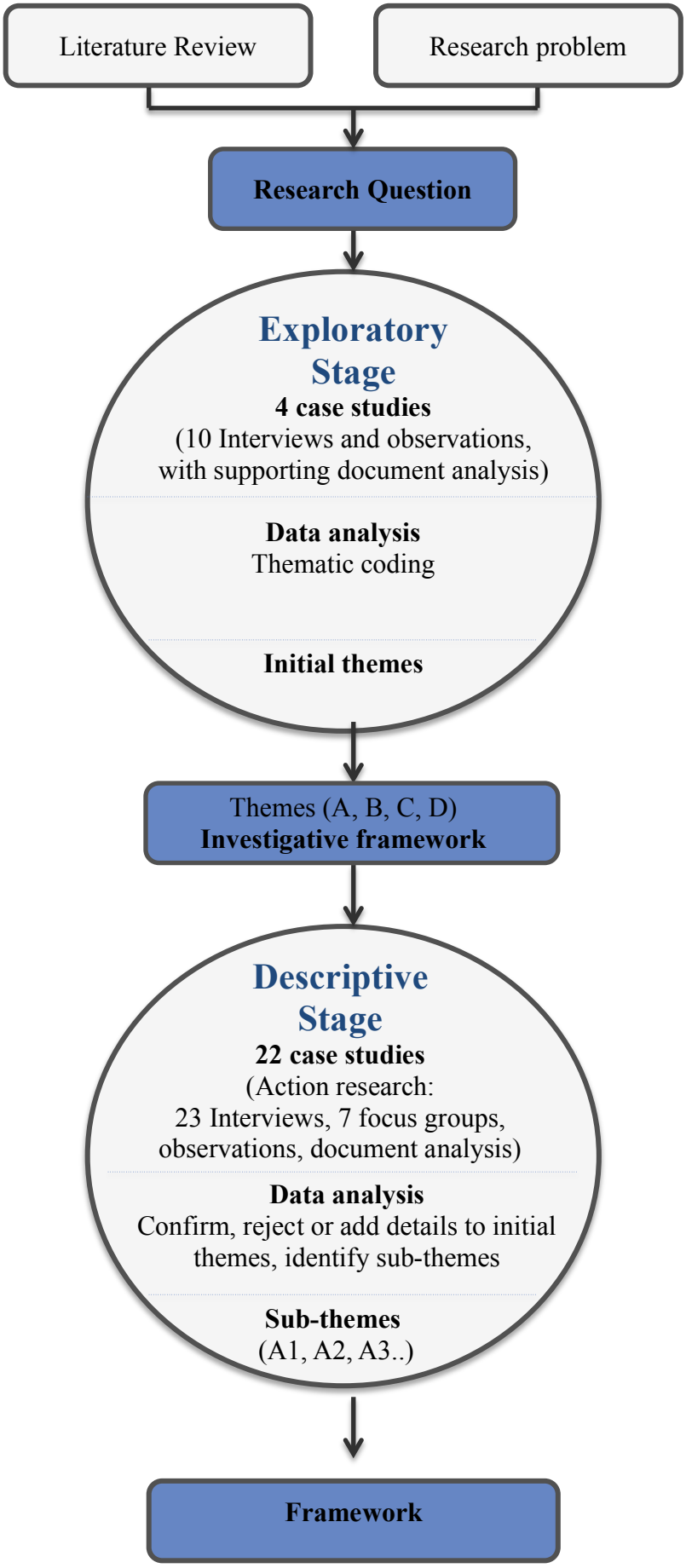
3.7 The research plan

This section will present the research plan selected to conduct the research to answer the research question.

3.7.1 Research in the real world

The researcher had to gain access to companies and individuals to conduct the case study research (the case selection strategy is described in later sections). The researcher had to find participants and get access to them. Gaining access was important, when the selected company gave access the researcher had to firstly go there, and then decided how long to spend with the company. For example you don't know whether you're going to spend 4 days there or 20 days, because you don't know how rich it's going to be. Access and flexibility were needed. Then re-visiting the plan regularly and adjusting. The below section describes what actually happened. The below is effectively a research plan with hindsight. Figure 6 highlights the research plan.

Figure 6. Research Plan



The research objectives and questions guide the selection of data collection methods and research design chosen to answer to research question.

3.7.2 Forming the Research Question

This section briefly describes how the research question was formulated.

The Industry problem discussed in chapter 1, and gaps in current knowledge presented in the literature review section in chapter 2, formed the basis of this research study and the research question.

The literature review presents the gaps in existing knowledge (I.e. What is already known about the topic, what concepts and theories have been applied to the topic, who the key contributors to the research on the topic are.). The objective of the literature review is to ground the research question in existing knowledge by addressing the gap this research seeks to close.

The existing literature was used to understand;

- Concepts and theories that are relevant to this research,
- Current knowledge and gaps,
- Methods and research strategies that have been employed in studying this area.

The literature review was used to define and refine the research question and research objectives that are presented below. The techniques used to conduct the literature review and how it was conducted is described in chapter 2.

Research question

- What abilities do companies need to improve their industrial sustainability?

The research question was answered by undertaking the research in two stages, using an exploratory first stage, which will inform the descriptive stage.

3.8 Exploratory stage

This section describes how the exploratory stage data collection & analysis was conducted.

3.8.1 Exploratory stage data collection

In the exploratory stage of the research **4 case studies** (Table 5) were used to observe and understand what abilities do companies need to improve their industrial sustainability? From this emerge high-level themes (i.e. abilities needed to improve industrial sustainability). Significant focal firm engagement was required to undertake this research; for example the researcher spent two weeks in the company, with access to senior management responsible for sustainability improvements and implementation in the organisation. Data was collected using interviews, observations and document analysis (Miles and Huberman, 1994).

The case companies selected were either world leading or advanced in their sustainability performance within their sectors. The cases were selected to come from different sectors. All have very clear and publically acknowledged leadership in sustainability within their sector. Data availability and accessibility were also determining factors in the case selection process. It was felt that this selection criteria would provide interesting insights into what abilities do companies need to improve their industrial sustainability.

The findings are based on 10 semi-structured interviews with 8 senior sustainability management participants (i.e. exploratory interviews with firms), document analysis (i.e. academic and practitioner-orientated literature, industry reports), site visits and observations (presented in table 5). The individuals interviewed had significant experience in the company sustainability improvement program and implementation. The interviews consisted of 1 to 3 senior management; each interview lasted between 90–120 minutes and was further supported by archival documents and observations. The interviewees were selected based upon their knowledge of the research area (i.e. public presentations, news articles, presentations, blogs of them). 10 Semi-structured interviews were conducted in the exploratory stage. The semi-structured interview

focused upon the research question and sought to understand the specific experiences and insights of the participating organisations. All interviews were transcribed resulting in 83 pages of transcript (Chapter 4 presents the findings).

Company Code	Industry Type	Country Represented	Interviewee code / Job function	Semi-structured interview	Document analysis	Observation
C01	Automobile Manufacturer	UK	**1A -** General Manager for Environmental Affairs and Corporate Citizenship.	✓	✓	✓
C02	FMCG Manufacturer	UK	**2A-** Head of Communications, **2B**- Head of Engineering.	✓	✓	✓
C03	Clothing Retailer	UK	**3A-** Director of Sustainable Business, **3B-** Head of Sustainable Business.	✓	✓	✓
C04	SME Automobile company	UK	**4A** - Chief Engineer & Founder, **4B** - Systems & Sustainability Engineer, **4C-** Design & engineering.	✓	✓	✓

Table 9. Exploratory stage case studies

Table 9 constitutes: 4 organisations, 3 sectors, and 8 participants out which 6 are in senior positions, some director level or above. Case company C01 for example employing over 300,000 people, all 4 organisations are perceived leaders in industrial sustainability implementation.

3.8.2 Exploratory stage data analysis

This section describes how the exploratory stage data was analysed**.** The data analysis process followed Miles and Huberman (1994) and Yin (2009) guidance on tabulating, displaying, and analysing qualitative data. Figure 7 illustrates how the exploratory analysis was carried out:

- The researcher commenced the analysis by firstly reading through the interview transcripts from the stage one data collection.
- The researcher by **looked for patterns** within the data of; what companies are doing to improve their industrial sustainability? And in specific, what abilities do companies need to improve their industrial sustainability?
- The quotes that were interesting and provided evidence in answering the research question or the more general research objectives **were highlighted**.
- The interesting quotes that are highlighted were **physically cut out** of the A4 sheets of transcript into paper strips with company codes.
- The **quotes that are similar were grouped together**. By going through all the quotes, they were grouped into piles with other quotes that **seemed to have some commonality** – they represented a theme in the data. Initially about 4 thematic codes were established based on the inductive coding. This process is known as Inductive thematic coding (Boyatzis, 1998). How the exploratory stage coding was done is described in Appendix 7.
- The **title of the theme emerged out of the grouped quotes**. The themes represent key abilities needed for industrial sustainability.
- The preliminary findings from stage 1 of the data collection were used to **propose a high level framework** linking the themes (i.e. abilities) that will be used in stage two data collection. These themes are used as the starting points for the descriptive stage of the research.

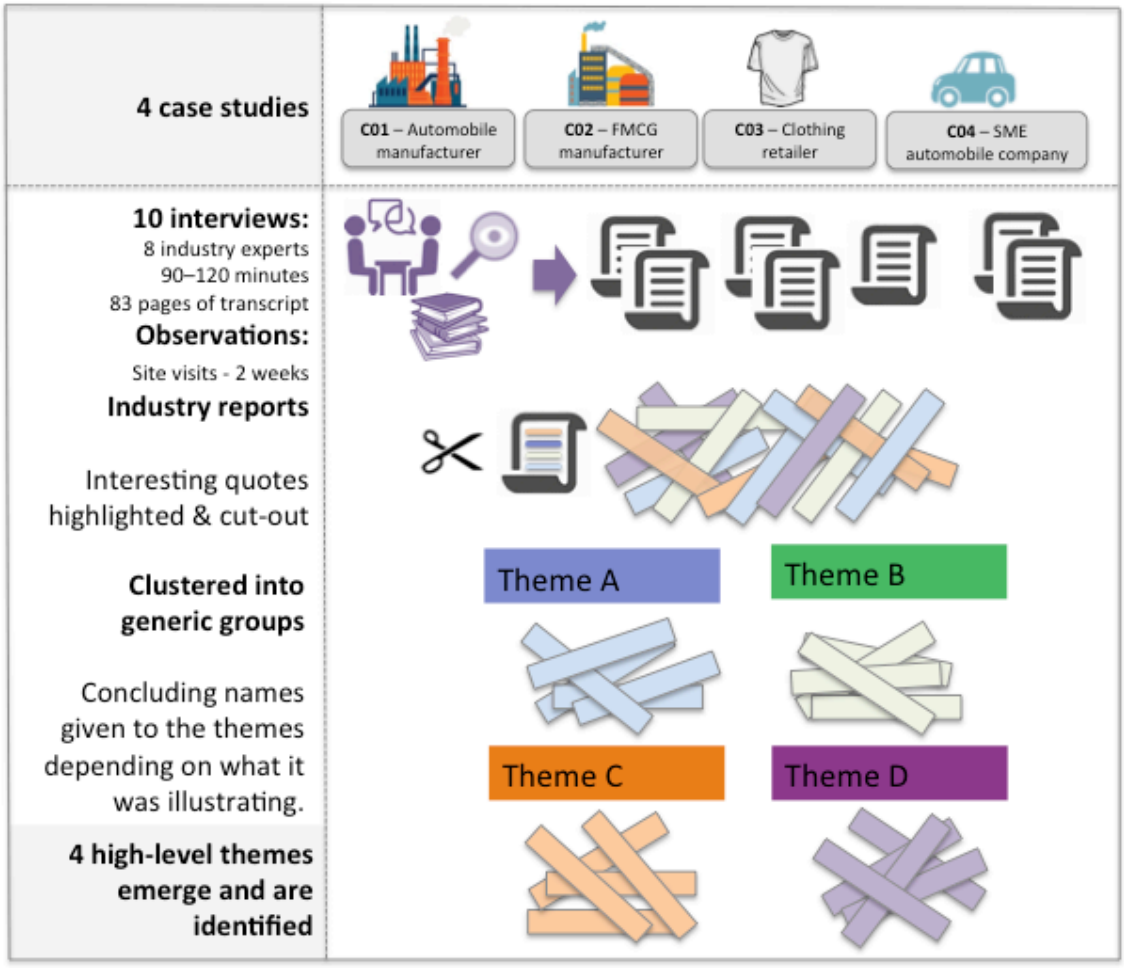


Figure 7. Exploratory stage analysis

3.9 Descriptive stage

This section describes how the descriptive stage data collection & analysis was conducted.

3.9.1 Descriptive stage data collection

The objective of the descriptive stage of the research is to gain a deeper insight into the themes proposed in the exploratory stage; new data are collected to confirm, reject or add detail to the themes. In the descriptive stage 22 organisations are used to conduct action research; 23 interviews with 15 companies and a total of 27 participants (table 6), 7 focus groups with industry with a total of 128 participants

(Table 7), 7 site visits, and document analysis are used to collect data.

The researcher seeks to provide an accurate description of observations of the themes proposed (i.e. better understand any sub-themes that comprise the themes proposed in the exploratory stage). The themes are incorporated into an investigative framework that is used within case companies to create an action, to stir up a reaction and observe the reaction of participants.

➢ Interviews

In the interviews the researcher firstly briefly introduced the context of the research problem, proposed abilities and the research project to the interviewees. The interviewees were presented with the investigative framework, based on the exploratory stage, and their reactions sought and recorded to gain insights into their understanding of the proposed abilities (themes) and how they are being used or can be used in their organisations.

This section presents a brief introduction to the 15 organisations interviewed,

Company Code	Industry Type	Country Represented	Interviewee code / Job function	Semi-structured interview	Document analysis	Observation
C05	FMCG Manufacturer	UK	**5A-** Sustainability Manager UK.	✓	✓	✓
C06	Multinational conglomerate Manufacturer	USA	**6A** -Project manager, Corporate Environmental Programs.	✓	✓	✓
C07	Design and manufacture of ejection seats	UK	**7A** – Engineer.	✓	✓	✓
C08	Brewer	UK	**8A-** Environmental Sustainability Manager.	✓	✓	✓
C09	Retailer (Footwear & Apparel)	DE	**9A-** Deputy Head Sustainability, **9B-** Global Sustainability Director, **9C**- Supply chain Director.	✓	✓	✓
C10	Textile (Carpet)	USA	**10A-** Sustainability	✓	✓	✓

	Manufacturer		Director.			
C11	Furniture & shelving systems Manufacturer	UK	**11A-** Owner/ Managing Director. **11B-**Engineer.	✓	✓	✓
C12	Retailer (Apparel)	UK	**12A-**Environmental sustainability coordinator, **12B-** Sustainability Director.	✓	✓	✓
C13	Manufacturer of accessories made from reclaimed materials.	UK	**13A-**Founder & Owner, **13B-** Master craftsman.	✓	✓	✓
C14	Hazardous chemicals member coalition	DE	**14A**-Committee head, **14B**- Members.	✓	✓	✓
C15	Sustainable clothing & footwear member coalition	USA	**15A-**CEO, **15B**- Members.	✓	✓	✓
C16	Entrepreneur & Industrial sustainability innovations subject expert	USA	**16A-** Initiator of The Blue Economy.	✓	✓	✓
C17	Manufacturer of accessories made from reclaimed materials	BCN	**17A-** Owner, craftsmen & tailor.	✓	✓	✓
C18	Academic/ Manufacturing Industry expert	UK	**18A-** Director centre for Industrial Sustainability.	✓	✓	✓
C19	Retailer (Footwear & Apparel)	USA	**19A-** Director Sustainable Business & Innovation, **19B-** GM Sustainable Business and Innovation **19C-** Systems Innovation, **19D-**Senior Director Systems Innovation, J **19E-**Senior Director Manufacturing Revolution New Technology Exploration, **19F-**Director, Communications & Network Mobilization.	✓	✓	✓

Table 10. Descriptive stage interviews

Table 10 constitutes: 15 organisations, 9 sectors, 5 countries and 26 participants out of which 19 are in senior management positions, some director level or above, all organisations are perceived leaders in industrial sustainability implementation.

➢ Focus Groups

This section introduces the 7 Focus Groups. Data was collected by observing workshops.

Each workshop (1-2days, 7.5 hour) involves between 8 and 35 participants, who were brought together at one location to discuss the abilites proposed to improve sustainability performance. The abilities already identified in stage 1 of this research were introduced to focus groups in a workshop and questions were asked in a structured way (Chapter 5 presents the investigative frameworks and questions) and their reactions observed and documented. Focus groups were selected as they are highly interactive and can attain information from people with different perspectives about a problem. Furthermore they can provide an overall appreciation of a problem that rarely emerges from other data collection methods like individual interviews or surveys (Van de Ven, 2007). The focus groups included participation of senior level managers representing the CEO, manufacturing operations management, sustainability management, IT, Finance, supply chain, R&D and Innovations functions within the organisation and also some external actors such as NGOs and academic experts. The workshops were conducted with multiple participants to get feedback from a wider range of people with different areas of expertise. Each workshop evolved around a carefully structured group process for gathering of data to ground the research problem and minimise bias (Van de Ven, 2007). Table 7 presents the focus groups, and below some pictures of workshops and site visits are presented (Figure 8).

Company Code	Industry Type	Country Represented	Participant Job function	Focus Groups (Participants)	Document analysis	Observation	Mfg. Site visit	Action Research
C20	Apparel (Jeans) Manufacturer	VT	Business owner-CE0, manufacturing operations management, compliance, sourcing, GM, finance and IT	13	✓	✓	✓	✓
C21	Industry workshop (footwear, academics, aerospace, designers)	UK, USA	Innovations management, academics, designers, operations management, sustainability management	20	✓	✓	✓	✓
C22	Apparel Manufacturer	SR	Manufacturing operations management, suppliers, innovations, product design, IT	24	✓	✓	✓	✓
C23	Apparel Manufacturer (End to end supply chain)	IND	Manufacturing operations management, sustainability management, academics	10	✓	✓	✓	✓
C24	Apparel Manufacturer	SR	Manufacturing operations management, innovations teams, sustainability management	18	✓	✓	✓	✓
C25	Sustainable Apparel & Footwear Coalition	USA	Sustainability management, NGO, academics, retailers,	35	✓	✓	✓	✓
C26	Packaging & label Manufacturer for the apparel & food industry	SR	Business owner-CE0, operations management, innovations management, sustainability management.	8	✓	✓	✓	✓

Table 11. Descriptive stage focus group

Table 11 constitutes: 7 organisations, 5 sectors, 5 countries, and 128 participants in total out of which 45 are in senior management positions, director level or above.

Company C20 Workshop
(13 Participants)

Company C24 Workshop
(18 Participants)

Company C22 Workshop
(24 Participants)

Company C26
Manufacturing site visit- Packaging & label manufacturer developing the ability to see environmental and social waste.

Company C20
Manufacturing site visit- Apparel manufacturer aerial drying jeans saving significant amount of energy.

Company C22
Manufacturing site visit- Apparel manufacturer Eco Factory.

Figure 8. Company workshops and site visits

3.9.2 Descriptive stage data analysis

The aim of the analysis was to confirm, rejected or added details to a theme from the exploratory stage. All interview and workshop transcripts, supporting documents, and personal notes were analysed and coded according to the themes they represented. Figure 9 presents how the descriptive stage analysis was carried out.

- For each organisation and workshop the data was studied to confirm, reject or add detail to the 4 themes.
- After finishing all 26 organisations,
- New data within each theme was grouped together according to what seemed to have some commonality. From this emerged sub-themes that make up the theme; these were coded as for example (sub-theme A1) (Sub-theme A2), (Sub-theme A3). The analysis and coding of the sub-theme is illustrated in Appendix 7.
- Each sub-theme was then compared against existing literature to check whether it confirms, rejects or adds detail to the currently published knowledge.

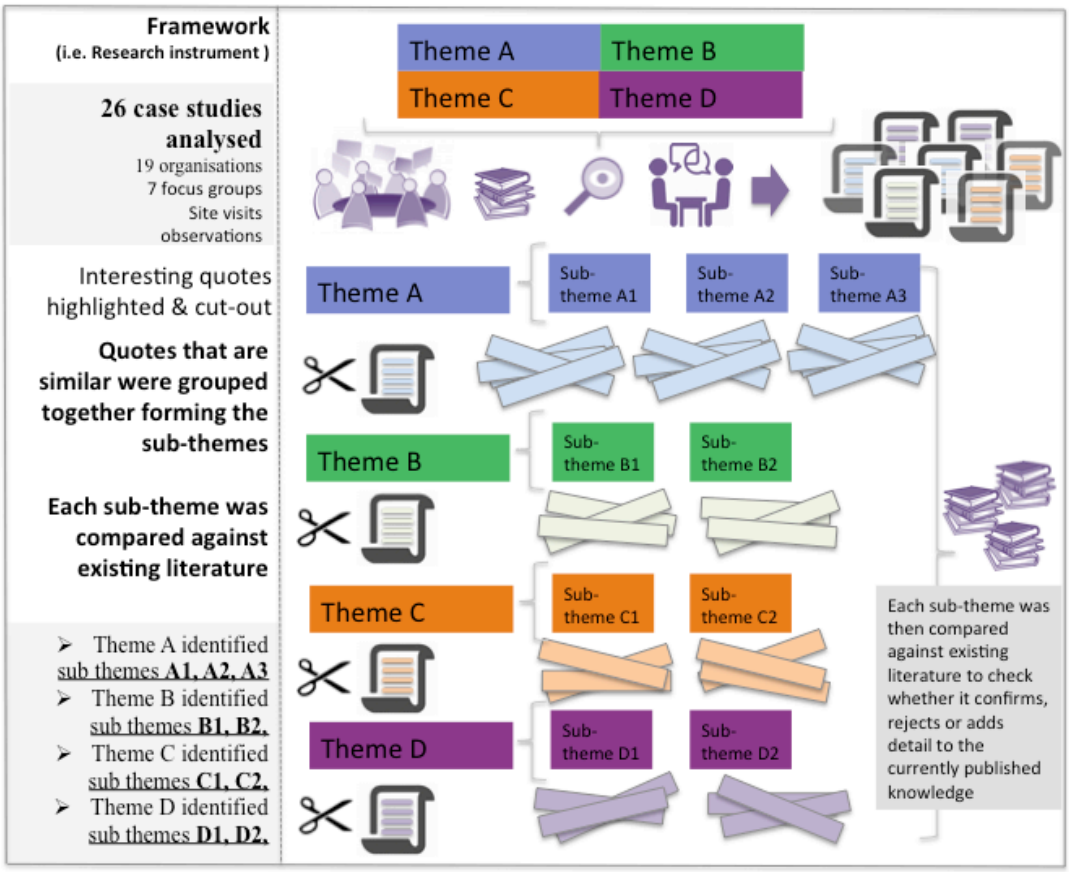


Figure 9. Descriptive stage analysis

3.10 Chapter conclusion

In summary, this chapter presented the philosophical and methodological considerations and the decisions made by the researcher to develop an appropriate approach to carry out the research.

Chapter 4
Introduction to cases of exploratory stage

This chapter presents the case studies explored in the first stage of the research. The aim of this section is to explore from practice case studies, what abilities do companies need to improve their industrial sustainability.

4.1 Stage 1 exploration process

The objective of this stage of the research is to better understand,

- **What abilities do companies need to improve their industrial sustainability?**

The exploratory case studies of 4 companies is used to observe and identify **high-level patterns themes** in what abilities do companies need to improve their industrial sustainability. The findings are based on semi-structured interviews (i.e. exploratory interviews with firms), site visits, observations and document analysis (i.e. academic and practitioner-orientated literature, industry reports) conducted in the first stage of the research. The four case companies were selected to represent a range of industrial sectors that have actively invested in sustainability initiatives, strategies and practice and provide evidence on what they have done to improve industrial sustainability performance within their organisation. The case studies were selected to exhibit a relatively mature level of performance within the sector. The case studies are organisations that had some level of published sustainability credentials (i.e. that might support advanced sustainability performance). The interviewees were individuals in senior positions responsible for implementing and managing the sustainability improvements in the organisations. In addition, data availability and accessibility were determining factors in the case selection process. Each case complemented the others by replicating the findings under various conditions or by addressing different aspects. The goal was that together the set of case studies would

provide empirical evidence for what abilities do companies need to improve their industrial sustainability.

The exploratory stage aims to provide understanding of what abilities do companies need to improve their industrial sustainability, what are companies doing to improve their industrial sustainability, how are they doing it and from this emerge high-level themes (i.e. Abilities needed to improve their industrial sustainability).

4.2 Data collection stage 1 (exploratory stage)

This section briefly presents the 4 case studies explored in the first stage of the research; the high level facts and patterns that emerge are presented on what companies are doing to improve their industrial sustainability and what abilities do companies need to improve their industrial sustainability.

- Company C01 – Automobile manufacturer
- Company C02 – FMCG Sugar manufacturer
- Company C03 – Clothing Retailer
- Company C04 – SME Automobile company

Company C01 – Automobile manufacturer

Interviewee: 1A- General Manager for Environmental Affairs and Corporate Citizenship

A well-reputed automobile company with a global footprint, known for its sustainability credentials industry-wide and for its ability to reduce waste (i.e. labour & non-labour efficiency improvements). The company is viewed as setting benchmark standards in lean manufacturing in which **waste and inefficiency** are **continuously driven towards minimal levels**. Company C01 described, *"The aim is that the whole company should be* ***green, clean and lean"*** *(Interviewee 1A, transcript page 1).* The company is found to use 'guiding principles' and 'set challenging targets' to continually reduce environmental impact and disseminate this to all levels of each manufacturing plant. The company also has their own **ambitious vision to transition** ***'Towards the ultimate eco-factory'.*** The company's aim is to move towards a **net positive impac**t rather than just trying to reduce negative factors to zero. The company by developing **the ability to tackle and improve non-labour waste** has made some significant improvements in its sustainability performance.

The company's UK manufacturing plant has been able to achieve;

- Zero waste to landfill - achieved in 2003 (two years ahead of target)
- Waste water recycling - 100,000 tonnes of water saved per year
- CO2 reduction within the boiler house (4,500 TC02e per year below 2004 levels)
- Decoupling of CO2 emissions with increasing production volumes since 2003
- 25% reduction in energy use per vehicle in paint booths.
- Achieved **radical improvements** in its **resource efficiency,** between 1993 and 2013, it reduced its **energy usage per vehicle by over 70%.** In the same period it also **reduced water use per vehicle by over 75%,** and **waste produced per vehicle by nearly 70%.**

The company described tackling **resource efficiency** across ***four distinct areas; energy, CO2, water, waste materials and emissions to air*** *(i.e.* four major key performance indicators). The company sets its own, usually much more stringent, targets that the legislation requirement. *"Not only do eight of the company's European*

manufacturing sites have the ISO14001 environmental management standard, they have also achieved ***zero waste to landfill*** *and is the first company to achieve this in the worldwide automotive industry" (Interviewee 1A, transcript page 2).* The company describes its approach to environmental issues is the same as for all other aspects of the **continuous improvement - or 'kaizen' -** methodology that it applies in production processes. The company describes the manufacturing plant in the UK, had been the first to achieve "**zero waste"** and had sent no waste to landfill since 2003. The company describes, "*Waste was reduced as much as it could be, but where waste did arise at the plant it was segregated at source and recycled where possible. The sludge water content was removed from waste and incineration provided an opportunity to recover energy" (Interviewee 1A, transcript page 2).* The company described that following the example of the UK plant all the companies European manufacturing plants were able to reduce their waste and managed to send zero waste to landfill by sharing knowledge and **developing the ability across the organisation**. The company described how all plants were set the challenge of reducing the total amount of waste created and to move up the waste hierarchy, and increase their recycling to recovery ratio. The company described, **"*We want to be able to improve the performance of older plants and take the newer ones onto a different level*"** *(Interviewee 1A, transcript page 5).*

Source: Interview data *(Interviewee 1A - General Manager for Environmental Affairs and Corporate Citizenship)* & document analysis *(Company C01, 2015).*

Company C02 – FMCG Sugar manufacturer

Interviewee: 2A- Head of Communications & 2B- Head of Engineering

The company is a fast moving consumer good (FMCG) sugar manufacturer. The company is described to be one of the world's largest sugar producers; producing over 420 kt of sugar annually for the food and drinks industry. The company is describes it is an advanced and sustainable manufacturer with a real commitment to its people and planet. The company believes its business decisions should simultaneously benefit the environment, its stakeholders and the communities in which it operates. "*We are committed to building a long-term, robust and resilient business and to achieving our*

vision of becoming the world's leading sugar business. To do this, we respond to the many challenges and opportunities that arise from climate and population change while ensuring that ***continuous improvement and operational excellence drive efficiency,*** *allowing us to make the most of every stick of cane and root of beet" (Interviewee 2A, transcript page 6).* The company described focusing its efforts on improving **energy efficiency, water use, agricultural productivity** and **engaging beyond the factory with the wider community** and being committed to acting in a socially responsible manner.

The company uses a culture of **innovation to reduce process inputs, minimise waste and deliver its commitment to be an advanced and sustainable manufacturer**. The company converts raw beet to sugar and the byproducts are used to produce electricity, tomatoes, animal feed, and other materials. **No material arriving into the company is allowed to disappear as waste (and a cost). Instead all materials are turned into valuable co-products**, including the soil attached to the beet, which becomes clean soil for gardeners, these actions contribute to a **very high level of efficient use of raw materials**. The company has been able to **bring more value under its control** and link knowledge to benefit by **turning everything into a valuable output**. The company has over an extended period of decades, develop the ability to **find waste** and **creatively capture and uncover new value opportunities**. The company describes, this ability to **see all materials as potentially valuable, encourages the staff to find and** develop new lines of business. The company stated that by developing this ability the company has been able to expand into tomatoes and bio-ethanol production by capturing its waste and making it valuable. The '**opportunity thinking**' **culture** and those with the process knowledge being empowered **to identify innovations** to be taken forward is described as aiding the ability to **uncover new value opportunities**. **"***We are always looking for people with a can-do attitude and an insuppressible passion. Natural leaders with tenacity, an enquiring mind and the ability to deliver innovative yet practical solutions. We are interested in individuals who have talent, drive and a real hunger for rapid advancement" (Interviewee 2B, transcript page 8).* The company invests in skills and capital heavily, the company has used a high capital and high knowledge strategy to improve efficiency, which has resulted in the company becoming the 2nd cheapest

place to grow and produce sugar in the world. *"Our people use their skills and knowledge to get the most from our investments across the supply chain. By focusing on driving efficiencies within our business, we use our raw materials as effectively as possible to minimise waste and create more from less" (Interviewee 2B, transcript page 9).*

Core business innovation is described as helping the company remain competitive, whilst the development of co-product lines provides a diversified supplementary income. **Collaboration with suppliers is described to be important in the company's journey to many of the improvements**; from working with farmers to improve yield, optimise fertilizer use and extend the producing season, to **collaborating with external actors** to optimise the operation of its CHP gas turbine. The company describes *"Careful consideration of when to partner, when to bring expertise in, and when to outsource new co-product operations has also underpinned the development of new lines of business" (Interviewee 2B, transcript page 9).* The company described how, by developing this **ability to create value from waste**, revenues are generated by the sale of co-products, and costs are avoided by **sending less material to landfill.**

Source: Interview data (*Interviewee 2A- Head of Communications & 2B- Head of Engineering),* document analysis *(Company C02, 2015).*

Company 03 - Clothing Retailer

Interviewee 3A: Director of Sustainable Business, 3B- Head of Sustainable Business

The company sells clothing for men, woman and children, as well as home products and food. The organisation in 2007 launched a [Sustainability change program] to help protect the planet by sourcing responsibly, reducing waste and helping communities. The aim of the [sustainability change program] is to aid the organisation become carbon neutral, send no waste to landfill, extend sustainable sourcing, help improve the lives of people in their supply chain and help customers and employees live a healthier life-style. The company did this by setting out 100 commitments to achieve in 5 years from 2007. The company now has introduced [Sustainability

change program 2020]; which consists of 100 new, revised and existing commitments, with the ultimate goal of becoming the world's most sustainable major retailer. As part of the change program the retailer is described to be working closely with its supply chain partners and manufacturers to develop eco-factories. For example some of the clothing manufacturing plants are described to have been able to reduce the factory's energy use, carbon footprint and waste significantly through this initiative and collaboration.

The company describes *"Successfully achieving [Sustainability change program 2020] will take [Name of Company] from completing roughly 20 % of its sustainability journey today, to around 40%, but to go beyond that will require an entirely new way of doing business. I think you can make an existing business model 40% better than it was 10 years ago in terms of waste, water, energy etc. You then run into the limitations of your existing business model, which was designed in the 20th century to make things in a linear way. If you're going to get to 100% sustainable you will need a new business model" (Interviewee 3A, transcript page 11)*

In addition to tackling sustainability challenges within its supply chain partners and manufactures. For example, the retailer is working with farmers in India to develop ways of producing cotton that use less water and fewer pesticides. The company describes the importance of being able to develop the ability to form collaboration and relationships with a charity organisation (unusual partner). The collaboration aids the company to develop and implement a unique business model, which allows unwanted clothing items to be resold, reused or recycled by a charity partner (i.e. NGO). The company describes by collaborating with unusual partners, it has been able to start finding some solutions to issues such as waste to landfill. The company describes through the collaboration the company has been able to leverage on the charity firms collection and distribution expertise. The collaboration with the non-profit firm is described to have diverted a significant portion of clothing out of landfills and also benefited the NGO and planet.

Source: Interview data (*Interviewee 3A- Director of Sustainable Business, 3B- Head of Sustainable Business*) & document analysis *(Company C03, 2015).*

Company C04 - SME Automobile Company

Interviewee: 4A - Chief Engineer & Founder, 4B - Systems & Sustainability Engineer, 4C- Design & engineering

The company is a UK based automotive company, aiming to **produce highly efficient vehicles f**or personal transport. The vision for the company is "***to produce mobility at zero cost to the planet****" (Interviewee 4A, transcript page 15).*

The company has an interesting business model, which is based on **sale-of-service** (i.e. Mobility as a service), the company offers a new business design which is described to **take a whole systems view to create new forms of value**. The company sells mobility to the driver and they (i.e. the company) pay for the fuel. The company describes, *"We're a different sort of car company. We'll never sell a car as a product. We offer mobility as a service. For a fixed monthly fee our customers will receive a car – their car – and all the maintenance, insurance and fuel to run it. One payment to cover everything – at the equivalent monthly cost of running a normal, average car" (Interviewee 4A, transcript page 15).* The company describes this **unlocks a new value system** that allows them to build 250-mpg (e) cars. The organisation offers an **innovative business model** where the company sells mobility by charging customers a fee per month and per kilometre, the company then pay for the fuel.

The company describes "*Our car has been designed from scratch to **deliver a step change in fuel efficiency and environmental performance**. The overall design of the car gives us a groundbreaking **efficiency and range**, many times better than inserting fuel cells into conventional, heavy, vehicles" Interviewee 4C, transcript page 16.* The company strives to achieve zero cost for the environment. The company describes, "*If you are motivated to sell new cars, you become less inclined, for example, to **use the most durable materials**. The [name of Company] have coined the phrase '**selling mobility as a service**' – cars are offered as part of a service contract. At a result, designing cars of **excellent and lasting quality becomes good business sense**; whilst the unsustainable practice of 'designing for obsolescence' –deliberately designing cars that the customer will soon wish to replace, becomes a thing of the past" (Interviewee 4A, transcript page 16).*

The company offers an example of how it has **found advantageous connections across the system** and illustrates maturity in the **whole systems design ability**. The car company, by taking a systems view, internalised the fuel cost, the company pays for the fuel and customer the distance travelled has been able to design lighter and longer lasting cars. Furthermore, the company describes, using an innovative governance model, which seeks to **improve the interactions and collaboration between stakeholders** (i.e. investors, users, staff, suppliers/infrastructure partners, the environment and community) to ensure broader aligned **sustainable value creation**. The company describes, *"We want **to deliver value in all these domains** – it's **good for society** and we think it's also better business" (Interviewee 4A, transcript page 16).*

Source: Interview data (*Interviewee 4A - Chief Engineer & Founder, 4B - Systems & Sustainability Engineer, 4C- Design & engineering)* & document analysis *(Company C04, 2015).*

4.3 Chapter Summary

The section provides an understanding of what the chosen case companies are doing to improve their sustainability performance. Four exploratory cases have been chosen so that they offer insight from different sectors and at different scales, while all are clearly either world-leading or close. The four cases presented clothing, automotive, and food sectors, with company size ranging from a start-ups to some of the biggest companies in their sector. All have very clear and publically acknowledged leadership in sustainability within their sector. The company C01 described how it has been able to reduce its energy usage per vehicle by over 70%, water use per vehicle by over 75%, and wastes produced per vehicle by nearly 70% and also send zero waste to landfill in in its manufacturing plants. Company C02 described focusing its efforts on improving energy efficiency, water use, agricultural productivity and engaging beyond the factory with the wider community and being committed to acting in a socially responsible manner. The company described the use of high capital and high knowledge strategy to improve efficiency, which has resulted in the company

becoming the 2nd cheapest place to grow and produce sugar in the world. Company C02 described being able to convert all its by-products into valuable output (e.g. converts raw beet to sugar and the byproducts are used to produce electricity, tomatoes, animal feed, and other materials). Company C03 described by developing the ability to collaborate with new organisation outside its firm boundary, it has been able to find solutions for the fast fashion waste to landfill problem. The case companies C03 and C02 emphasised on the importance of developing the ability to collaborate with new types of organisations outside the firm boundary. Company C04 a SME Automobile Company with a vision to produce mobility at zero cost to the planet. The company C04 and C03 described the importance of being able to develop new business models and develop the ability to redesign the system.

Chapter 5
Analysis of exploratory stage

This chapter presents the high level themes that emerge from the case studies explored in stage 1 of the research. The themes represent key abilities that might be needed for transition towards a more sustainable industry. Which then guide the enquiry in the descriptive stage. The preliminary findings from stage 1 of data collection are used to propose a high level investigative framework linking the themes (i.e. abilities) that will be used in stage two data collection. The high-level investigative framework is described and its logic is explained.

5.1 Analysis from stage 1 data collection

From the first stage of data collection 4 case companies were explored comprising; 10 semi-structured interviews, site visits, observations and industry documents review. The transcribed data were analysed using thematic coding, by clustering quotes and observing patterns in the data that suggest names for the themes that emerge out of the data. This process is described in chapter 2. The researcher looked for patterns within the data of 'what abilities do companies need to improve their industrial sustainability'. There were 2 broad sets of observations made across the data analysed.

- **1st set of observations:** there appear to be 3 stages of transition towards a sustainable industrial system observed over time.

Most companies described the transition towards **eco-efficiency** (i.e. doing more with less) as an important first step in the organisations journey in improving their sustainability performance. Company C01, C02, and C03 for example described examples of using fewer resources by focusing on reducing energy, water and materials. The transition towards **eco-factory** appears to be another interesting

transition. The patterns in the data across the cases (C01, C02, C03) and literature links the observed transitions by suggesting that manufacturers who have developed the ability and awareness to become eco-efficient and become good at it, and who seek to improve their rate of progress further, appear to move towards the eco-factory stage next (e.g. creating more value and enhancing resource efficiency). Company C01 described its vision to transition *'Towards the ultimate eco-factory'*. These visions of the future are described by companies, for example C01 envisions factories that could have a net positive effect on the environment and the society. The transition to this eco-factory stage is described as entailing the development of smart, resource efficient factories and investment in eco-technologies (e.g. use renewable energy, recycling technologies) to create more value and less waste (e.g. Company C02, C01). More advanced companies (e.g. Company C04) describe the importance of transitioning towards a more **sustainable industrial system** and implementing radically improved new whole industrial system redesign. Company C04 described how it was able to provide mobility as a service. There is some evidence and considerable logic that the transition to sustainable industrial systems occurs after the eco-factory is developed.

Overview of 1st set of observations

Transition from polluting to eco-efficiency

- **Stage 1** (i.e. short-term focus, becoming aware becoming efficient)

Transition from eco-efficiency towards eco-factory

- **Stage 2** (i.e. medium-term focus, becoming effective, using the best technological practice, doing the right thing, transforming the factories and products)

Transition from eco-factory towards a more sustainable industrial system

- **Stage 3** (i.e. long-term focus, becoming more ambitious, systems change, transforming the performance of the system, ability to make step change)

- **2nd set of observations:** there appear to be **4 sets of abilities** (What abilities do companies need to improve their industrial sustainability)

The 4 companies described, what they are doing to improve their sustainability performance? From this data set, patterns were observed on certain abilities the companies described they had to be good at. The data clusters formed 4 generic groups, which were eventually given a concluding name, depending on what it was illustrating. In the research 4 themes were identified through inductive analysis. Companies seeking to transition towards a more sustainable industrial system are observed to be becoming good at using some abilities. The 4 high level themes emerge from the cross case analysis as interesting abilities companies are developing over time (i.e. that might be needed to improve sustainability performance). The themes proposed and identified appear to be interesting abilities described by companies in response to the probe of 'what abilities do companies need to improve their industrial sustainability, what are companies doing to improve industrial sustainability, how are they doing it'.

Theme A - (patterns of improving efficiency related abilities)

The selected organisations appear to be focusing efforts on resource efficiency (i.e. non-labour waste). Companies such as C01 and C02 for example appear to be developing the ability to identify non-labour waste (e.g. energy efficiency, waste reduction, material efficiency) in their organisation and finding ways to reduce it significantly over time. The company C01 described how it has been able to reduce its energy usage per vehicle by over 70%, water use per vehicle by over 75%, and wastes produced per vehicle by nearly 70% and also send zero waste to landfill in in its manufacturing plants. Similarly company C02 described how it has been able to develop the ability to improve its sustainability performance by addressing resource efficiency improvements. Company C02 described focusing its efforts on improving energy efficiency, water use, agricultural productivity and health and nutrition. Most companies (e.g. C01, C02, C03) appear to have addressed non-labour resource efficiency as they started their sustainability journey. The improvements made by company C01 and C02 illustrate significantly better industrial sustainability performance is possible through resource efficiency improvements. Company C01

appear to have taken the route of developing challenging targets to reduce environmental impact and systematise the process of finding improvements.

Theme B – (patterns of internalisation of value related abilities)

Most organisations also described the importance of being able to seek value from waste. Company C02 for example described being able to identify opportunities to use waste from one process as inputs to another wherever possible. The company described how it has, over an extended period of decades, been able to creatively capture value opportunities. The company described how it was able to create and extract more value from its waste by converting all by-products into valuable output (i.e. internalisation of value). No material arriving into the company is allowed to disappear as waste (and a cost). Instead all materials are turned into valuable co-products (e.g. by-products are used to produce electricity, tomatoes, animal feed, and other materials). The company describes how they see all materials as potentially valuable, encouraging their staff to find and develop new lines of business. The Head of Engineering at company C02 describes *"our people use their skills and knowledge to get the most from our investments across the supply chain. By focusing on driving efficiencies within our business, we use our raw materials as effectively as possible to minimise waste and create more from less."*

Theme C – (patterns of collaboration related abilities)

All companies described the ability to collaborate as being important, some companies for example C02 and C03, specifically described the importance of being able to collaborate with actors outside its firm boundary (e.g. external collaboration with non-traditional partners) being important. Interestingly the data suggests that organisations that have been able to identify and work with partners outside the firm boundary have simultaneously been able to find solutions to complex sustainability related issues. Company C03 a clothing retailer talked about making resource efficiency improvements across its supply chain, for example working with farmers (i.e. partner in current value chain) to develop ways of producing cotton that use less water and fewer pesticides. The company also describes that by collaborating with a

charity organisation (e.g. non-traditional partner outside the firm boundary), the company has been able to develop and implement a unique business model, which allows unwanted clothing items to be resold, reused or recycled by a charity partner (i.e. NGO). The company describes by collaborating with partner outside the firm boundary, it has been able to find some solutions to issues such as waste to landfill. The company describes through the collaboration the company has been able to leverage on the charity firms collection and distribution expertise. The collaboration with the non-profit firm is described to have diverted a significant portion of clothing out of landfills and also benefited the NGO and planet. Company C02 also described the importance of collaborating with external partners (e.g. non-traditional partner outside the firm boundary). The company has used external collaborations to optimise the operation of its CHP gas turbine. The companies C03 and C02 both emphasised the importance of collaborating with new types of organisations outside the firm boundary.

Theme D – (patterns of **whole system design** related abilities)

The companies C04 and C03 described the importance of being able to develop new business models and develop the ability to redesign the system. Company C03 described *"Successfully achieving [Sustainability change program 2020] will take [Name of Company] from completing roughly 20% of its sustainability journey today, to around 40%, but to go beyond that will require an entirely new way of doing business. I think you can make an existing business model 40% better than it was 10 years ago in terms of waste, water, energy etc. You then run into the limitations of your existing business model, which was designed in the 20th century to make things in a linear way. If you're going to get to 100% sustainable you will need a new business model."* Company C04 is an SME Automobile Company with a vision to produce *mobility at zero cost to the planet*. The company described identifying new forms of value for their customers by innovative business models. Company C04 describes their joint design of a car and business model that deliver a step change in fuel efficiency and environmental performance. Company C04 takes a systems view to problem solving, and looks at the whole system, successfully identifying useful interactions between the components. The holistic systems approach to problem solving has led the company C04 to develop a radically new innovative business

model where the car manufacturer sells mobility to customer and the manufacturer pays for the fuel. This unlocks a new value system that allows them to build cars which achieve 250 mpg(e).

Overview of the list of high-level themes identified that emerge from the data:

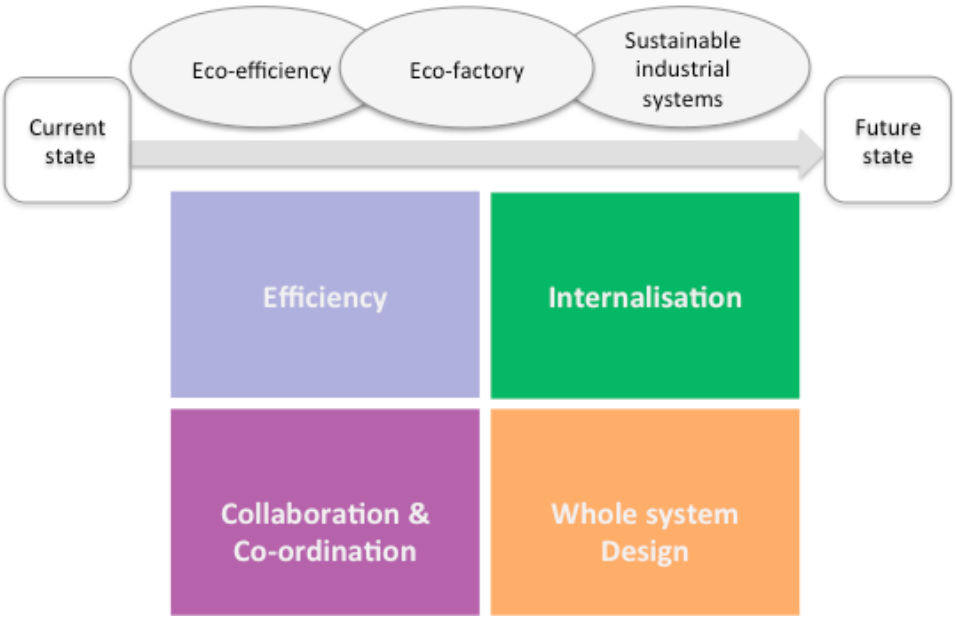
- **Theme A** (patterns of improving **efficiency** related abilities)
- **Theme B** (patterns of **internalisation** of value related abilities)
- **Theme C** (patterns of **collaboration** related abilities)
- **Theme D** (patterns of **whole system design** related abilities)

5.2 Proposed research investigative framework

The investigative framework is developed here to deepen understanding and explore further the abilities proposed (i.e. themes A- Efficiency, B- Internalisation, C-Collaboration, D-Whole system design) that may be needed for transformation towards a more sustainable industrial system (Figure 10. Proposed research investigative industrial sustainability ability framework). The primary purpose of the framework is to provide a visual representation of the themes, and generate deeper understanding of the themes proposed.

The framework is designed to stimulate ideas within manufacturers and encourage engagement between practitioners and researcher during data collection. This technique is followed to gather richer data and deeper insights. The framework will aid data collection in a participatory type research (i.e. action research) and support the empirical evidence collection. The framework will be used within action research cases. The investigative framework will be used to create an action, to stir up a reaction and observe the reaction. The researcher takes data from these situations into analysis (observations, notes, interviews both before and after, and documents) to find patterns in the data, which help answer the research question. The researcher will use the framework to approach the case study research, to firstly understand how the abilities proposed are used by the companies and further try to address possible improvements using action research methodology. The researcher intends to unlock and bring deeper understanding of the proposed abilities. The researcher will use interviews and focus groups as a data collection technique in the second stage of the research (i.e. descriptive stage). The framework will be presented to the company, the

proposed abilities explained by the researcher, seeking responses on for example, what matched and what didn't match their situation and what might be missing.



1. Introduce the 4 abilities (Efficiency, Internalisation, Collaboration, Whole system design) proposed
2. Understand the abilities proposed
3. What are you doing to improve your industrial sustainability?
4. Where are you now?
5. What do you need to be good at?
6. Where do you want to be in the future?
7. What matched and what didn't match and what might be missing?

Research Question

What abilities do companies need to improve their industrial sustainability?

Sub-questions

What are companies doing to improve their industrial sustainability?
How are they doing it?

Figure 10. Proposed research investigative industrial sustainability ability framework

5.3 Chapter summary

There were 2 broad sets of observations made across the data analysed. The first set of observations the researcher describes 3 stages of in industrial sustainability observed over a period time of time. From Polluting to eco-efficiency, to eco-factory, to then focus of transitioning towards a more sustainable industrial system being more long-term focus. The second set of observations the researcher describes are 4 interesting sets of abilities used by companied to improve their industrial sustainability. The four high level themes emerge from the case studies explored in stage 1 of the research; Theme A represents improving efficiency, theme B represents Internalisation of value, theme C represents collaboration, and theme D represents whole system design. The themes represent key abilities that might be needed for transition towards a more sustainable industry. The preliminary findings from stage 1 of data collection have been used to propose a high level framework linking the themes that will be used in stage two data collection.

Chapter 6
Analysis of Efficiency ability (Theme A) descriptive stage

This chapter presents the findings from the second stage of the research. The aim of the chapter is to explore in-depth and identify the sub-themes that comprise theme A (Efficiency). New data are used to elaborate on the theme, while adding new sub theme and findings to the theme. The findings are compared against the existing literature to show it adds new detail and contributions to knowledge.

6.1 Descriptive stage findings and analysis

In this section the new data are used to elaborate on the abilities found in the exploratory stage. The stage two data collection and analysis brings out sub-themes, which are evidenced and explained.

The format used to describe this section is presented below

Format:

Theme heading (Ability A, B, C, D)

The ability (theme) is compared with the literature to confirm current understanding and existing knowledge.

Findings from new sub-theme;

High-level introduction to sub–theme A1, A2, A3, etc.

⇒ An introduction to the findings from the cross-case analysis
⇒ Some details about the sub-theme is briefly presented

Data (empirical evidence)

⇒ Here verbatim quotes are presented to bring the sub-theme to life.

> **"……."**
> **Company code xx**

Authors' comments and discussion

⇒ This section uses the data to illustrate interesting details

The contribution to knowledge

⇒ This section compares the data to the literature, stating where it adds new details to, or where it confirms or rejects current knowledge.

⇒ Offers the authors final definition of the sub-ability (A1, A2, A3)

Define the theme

⇒ Bringing the sub-abilities identified for each theme together the author **defines the theme** (ability A, ability B, ability C, ability D)

6.2 Efficiency (Theme A) - current understanding and existing knowledge

The efficiency theme proposed by the author refers to evidence and observations found on the specific abilities that allow manufactures to effectively identify **non-labour wastes** and create more value using less resource by focusing on reducing energy, water and materials creatively and systematically. Waste here is interpreted in its widest form - not only the clearly visible material, but also energy, water and other resources.

Evans et al. (2015) in the report Industrial Evolution – Making British Manufacturing sustainable states "*the average manufacturer now spends five times more on non-labour costs than on labour costs. It is here that efforts to improve productivity should be focused.* The author also states *"many firms have already made staggering advances in their use of materials, water and energy. However too many others are not treating this as a strategic priority. Too many managers remain unaware of the extent of the benefits that could be achieved through greater efficiency".* The research on sustainable manufacturing in general and on eco-efficiency in particular is rapidly developing and crossing disciplinary boundaries. There are numerous well-developed concepts, which can contribute to industrial sustainability, While there is a growing amount of literature that contribute to understanding Eco-efficiency i.e. Material Efficiency, Sustainability, Waste Minimisation, Cleaner Production and Factor X, there is little knowledge available on how a manufacturer undertakes the transition (Von Weiszacker et al., 1997; Lovins, 2011; Despeisse et al., 2011; Schurig et al., 2015). Additionally, the work in this area is fragmented and clustered around technologies and tasks. On the topic of eco-efficiency many authors are putting forward energy and material efficiency ideas, but not talking about specific abilities needed to improve industrial sustainability. There is considerable literature on what organisations are doing to implement eco-efficiency **(**Lovins, 2011; Bocken et al., 2013; Despeisse et al., 2011); Authors have identified things companies need to be good at, some authors have attempted to answered that, actual tasks, a task based view, a technology-based view is available in the literature. The authors such as (Robèrt et al., 2002; Von Weiszacker et al., 1997; Lovins, 2011; Bocken et al., 2013;

Despeisse et al., 2015) provide numerous examples of sustainable manufacturing practices such as waste minimisation and sustainable manufacturing, which is the nearest literature that takes a transition view. The literature provides examples of operational practices for resource efficiency in factories and understanding of what organisations need to be good at; an ability-based view is not discussed. There is considerable organisational learning literature that can be viewed as applying to the challenge of implementing eco-efficiency, but they largely focus on generic change that can apply across any institution (e.g. Argyris, 1999; Senge, 2006, 2008; Brezet et al., 1997; Vezzoli and Manzini, 2011). Some authors are closer to providing understanding of abilities but do not contribute to specifically understanding eco-efficiency abilities. Manzini et al. (2008, 2011) tackles how designers might learn when pursuing sustainable industrial design, and Senge (2008) puts major emphasise onto learning that is relevant to bringing about industrial sustainability. This is a view that 'leaning' is a form of 'super-ability ' and implies that other abilities can be learned, (Senge, 2008) does not however take an ability-based view toward eco-efficiency and is more relevant to other abilities studied in this research. There also is a growing volume of industrial cases on sustainable manufacturing practices, but little is known on how these improvements were conceived, little is available about specific abilities (Teece, 2010; Barth et al., 2007; Segalas et al., 2009; Willard et al., 2010; Hesselbarth and Schaltegger, 2014).

The literature currently fails to provide evidence for what organisations are doing to develop their ability to identify and reduce non-labour waste systematically. In the following sections the research data is used to elaborate on this ability through the lenses of sub-theme.

6.3 Findings of new sub-themes of the efficiency (A1, A2, A3)

This section presents new or additional understanding on the ability of efficiency; this includes emerging sub-themes that are described and evidenced.

Sub-theme A1

23 from 26 case companies specifically referred to visualising waste as a key ability in their own journey, hence the author has chosen the **'ability to see waste"** as a probable ability which is explored in this section. The majority of the interviewees used the exact phrase '**see waste'** while all others used the term **'waste'** but did not use the phrase **'seeing',** instead they used phrases like **'finding'**, **'observe', 'looking'**, **'searching', or 'put on your glasses'**.

The term 'seeing waste' refers to forms of waste that are different to the traditional wastes that the manufacturing literature refers to, such as the 7 wastes of the Toyota Production System (Ohno, 1988; Liker, 2004). Most companies stated the ability to see waste was an important first step in the journey towards efficiency; the data here refers to environmental and social wastes such as unnecessary energy use or poor operator health. The sub-theme 'the ability to see waste' is a new type of ability to see 'non-labour resources waste' that organisations have not traditionally been good at addressing. This is important because the first stage of improvement action in many standard improvement methodologies is to understand an under-performance and in most manufacturers environmental and social waste is not automatically visible (e.g. we cannot directly see most forms of energy). Seeing waste such as labour and productivity losses is normal in most manufacturing firms, but seeing wasted energy is not. Organisations are found to be not as effective in tackling non-labour resource waste (Lavery et al., 2014) such as energy, material, water wastes. "*We hadn't looked at our factories in this way before…by being able to see the different waste streams…it helped us understand the root causes and where the wastes are occurring…some losses are very visible, others may not be so obvious such as water, as it is hard to visualize… but all have the potential to deliver significant financial and environmental benefit when spotted."* (Company C08). Those interviewed companies that are leaders in this field and who have been tackling resource efficiency for years, such as companies C01, C06, are found to be learning to see waste better.

Data on sub-theme A1 – 'ability to see waste'

(Note that all bold is the researchers emphasis and does not imply emphasis from the interviewee.)

*"**Finding waste is difficult**, it's **not easily noticeable, need to learn to identify and value waste.** For example water comes through pipes. Need to use your sensors and go to the location **and see, hear, feel to spot these wastes** such as water and air leaks. In addition meter readings, measurement, studying by observing and monitoring helps…The more experienced I have become the easier it is for me to **see the waste** in the process, yet, **my ability has developed very slowly**. I am often surprised when I walk the same process or return to an improvement made and suddenly discover new opportunities that I have never observed before. **Over time you learn to be much more observant**"(Company C26, workshop participant, transcript page 75).*

*"The first challenge is to understand how effective you can be right now. You also have to **wear the right 'glasses'** when reviewing your own production. When you step into the factory, you have to look at the processes, energies and resources wasted…The **ability to see waste is an essential skill to learn** … over a period I **learnt to put on a different pair of glasses and to see factories in a different way.** All of a sudden **I began to see waste that I had never been able to see before. Once you could see it, it really wasn't that hard to get rid of it**… Organisations that learns how to manufacture its products, but uses less water, materials and energy in doing so is going to have a cost advantage, as well as an environmental advantage, as well as a resilience advantage..."(Interviewee 18A- Director centre for Industrial Sustainability, transcript page 51).*

*"Encourage them to '**go and see'**, we refer to it as '**get your boots on'** and tackle wasted energy use. We know that by **walking through the plant** and applying the process and toolset, the teams will **become aware** of not only the **wasted energy,** but also of its impact on the facility's bottom line... By the time teams return to the central location in the early evening, you can sense the buzz, employees have **seen opportunities for improvement**, and are **understanding how this entire process makes sense for the organisation as a whole**…While the main purpose of Energy Treasure Hunt is to **identify opportunities to use resources efficiently**, the significant net impact is the **start of a culture change.** While efficiency projects are the direct outcome of the hunt, [Company C06] has trained more than 3,500 of its employees globally **to think about wasted energy and water in a different and powerful way**"(Company C06, Interviewee 6A -Project manager, Corporate Environmental Programs, transcript page 19).*

*"You need to know what the current situation is. For example, what is the current situation? **You can only tell by actually going to the place where that process has worked, to understand how it is operating**. We call this '**genchi genbutsu'- 'go, see and study'**. And more importantly **go and talk to the people who are operating those processes on a daily basis.** They are the experts; the engineers are not the experts in this case. You cannot understand a process by sitting in your office. You have to **go out there and understand the process**…. And **making things visible** is one of the key points." (Company C01, Interviewee 1A- General Manager for Environmental Affairs and Corporate Citizenship, transcript page 3).*

6.3.1 Discussion sub-theme A1 (ability to see waste)

Interestingly the data suggests, that those leading-edge manufacturing companies which have become effective at being 'able to see labour waste' are now shown to be using this same ability (e.g. skillset) to see new types of wastes. Many are now 'able to see non-labour waste', including wastes that are not easily visible (e.g. Companies C01, C06). But this is not automatically so; some companies who have a long history of ability in seeing labour waste showed no evidence of being able to transform that ability into seeing non-labour waste; for example workshop participants in company C23 stated "*We have focused our efforts to offer our customers speed replenishment programmes and focused on capacity creation and lean. We are only now starting to ask questions and finding ways to developing the abilities and skills to understand how we can capture value from the tonnes of off-cut fabric waste, improving energy consumption inefficiencies within the factories, effective ways to treat water discharge in our manufacturing processes and achieving zero waste to landfill*" (*Company C23, workshop participant, transcript page 64)*.

90% of the companies interviewed directly referred to the importance of 'seeing waste'. For example *company C01 stated that "go, see and study, making things visible" being a very important part of their journey.* The data across the cases illustrates the importance and ubiquity of this ability; it seems that manufacturers are increasingly learning the new behaviour of putting on these different glasses (i.e. seeing their manufacturing processes differently) and finding the different types of non-labour waste such as energy, material, water wastes.

The data across 26 cases analysed suggests that although manufacturers are putting considerable focus into becoming leaner and cleaner, improving performance and efficiency, and removing waste, they have only recently been paying more attention to less visible forms of waste i.e. such as energy and heat loss, leakage and inappropriate use of compressed air, and unnecessary water use.

The data also interestingly suggests a connection between 'seeing waste' and 'the importance of being at the location' i.e. being physically present at the location where the waste occurs to see and understand root-causes for the wastes in the process. The

majority of the firms confirmed that the ability to see waste and walk around the production area is necessary. In this instance the research specifically highlights the ability to look at the system not from the eyes of a lean specialist improving flow by analysing value add but from the view of improving material, water, energy flows. Across the cases there is strong evidence for the ability of 'seeing waste' that some leading manufacturing practitioners have been able to develop, while others are found to be only now starting the journey. Companies (example C01, C08) that are able to develop this ability offer evidence for its utility in reducing the amount of energy, water and material they use to produce each product and create more value. Which has also led to less toxic products and less polluting manufacturing processes such as companies C01, C02, C05, C08, and C10.

Much of the literature on the Japanese production system talks about 'seeing waste'; 'Genchi Genbutsu' is a Japanese phrase that means "go and see" and it is a key principle of the Toyota Production System (Ohno, 1988; Liker, 2004). Evans (2009) describes in recent times the quality and lean revolutions as having shown us a new, improved way of organising design and production and taught us new ways of seeing 'waste'. The existing literature on lean manufacturing refers to the 'seeing waste' ability to improve labour waste (defects, overproduction, transportation, waiting, inventory, motion, processing). Although the sub-theme A1 'seeing waste' in the research finding is referring to a different type of waste (i.e. non-labour waste), this does support the argument that this is one of the key sub-themes in eco-efficiency. The sustainable manufacturing literature places emphasis on the ability to operate plants efficiently (Von Weizsacker et al., 1997; Hawken et al., 1999; Ehrenfeld, 2009; Graedel et al., 1996; Schdmit-Bleek, 2009; Rashid et al., 2008; Despeisse et al., 2015). The literature on resource efficiency emphasises the importance of using resources with care (such as Rashid, 2008) but no authors were found that studied the ability needed to deliver resource efficiency. Zokaei et al., (2013) in the book 'Creating a Lean and Green Business System' and Esty and Winston, (2009) in the book 'Green to Gold: How Smart Companies Use Environmental Strategy to Innovate, Create Value, and Build Competitive Advantage' provide numerous examples of companies going lean and green simultaneously. The authors (Zokaei et al., 2013) use case studies to provide understanding of the challenges, opportunities,

tools and techniques that can be used in the path to becoming lean and green; A ability-based view is not discussed very often. Zokaei, Lovins and Hines, (2013) come closest in their comments describing "many well-known lean organisations that are widely acclaimed for their business excellence, among them Toyota, are simultaneously investing in improving their environmental performance by drawing upon their technical lean capabilities as well as their continuous improvement culture to push the boundaries of environmental management and resource efficiency".
Over 90% of interviewees used the metaphor of 'seeing waste', often spending extensive periods of time explaining the importance of this ability (i.e. sub-theme A1) and describing how they go about gaining the ability, which strongly supports the authors view that seeing waste is a key sub-theme of efficiency in industrial sustainability. It was repeatedly stated that if an organisation is able to see non-labour waste, then they are able to start doing something about it (Company C01, C06, C18, C26).

The sub-theme A1 (ability to see waste) is a confirmed theme of the efficiency (Theme A). Bringing the data together the author therefore proposes to define the sub-theme A1 as **'ability to see environmental and social waste'**.

Sub-theme A2

11 from 26 case companies described the exact phrase 'creative-thinking', 'thinking outside the box' and 'ingenious' as an ability in their own organisations to reduce environmental and social waste. The author has grouped these and chosen the **sub-theme A2 as 'ability to creatively reduce environmental and social waste "** as a probable ability which is explored in this section. Company C01 for example has been able to reduce the energy it uses to manufacture one car by 77% with negligible capital investment in new technology through the use of creative thinking and careful planning.

Data on sub-theme A2 - 'ability to creatively reduce environmental and social waste'

"For every pair of jeans another competitor laundry washes, we wash 23.3 jeans. A traditional laundry of the same size, producing 350,000 to 400,000 units per month, would normally use 600,000 litres of water daily. The new [company name] laundry uses 600,000 litres, only on the first day of operation, and every day after uses 30,000 litres. This is possible because [Company name] recycles 95% of its water. Solar panels blanket the roof of the building and supply renewable energy throughout the facility. The warm panels are used to heat water…. The Jeans are dried using ***recycled heat*** *from machines…. chemicals were selected and implemented that* ***could dye garment at room temperature***, ***eliminating the need to use energy to heat water.****..We also* ***aerial-dry our jeans,*** *our competitors don't do most of this…why use electricity and an industrial drier to generate heat, when the surrounding temperature is 35°c…****ingenious thinking and thinking out of the box helped us find these solutions****" (Company C20, workshop participant, transcript page 55).*

"We collect more than fifteen materials that go to landfill, always ***seeking a permanent solution for that particular material problem****. Many of our materials are found as we hunt through landfills, industrial estates, or form unique commercial partnerships to help our partners with their waste issues…* ***We use creativity in finding and designing solutions for this problem****… the pieces we make have to make* ***the best possible use of and create the most value from the raw materials (waste)*** *this is how we honour them… We work backwards, so we start with the material. We look at how much there is, what it can do* ***and how we might be able to work with it. What are its limits, its realities****… Then we think about what we could make, what that might cost, and what potential market might be suitable. After this research we prototype and test products at length before launch... Our recent project is with finest quality leather off-cuts…Our leather partners cherish their hides, the waste they produce is in small* ***seemingly unusable pieces****… We found a creative modular design approach as a solution to use this waste. We created three shapes that can interlock with infinite potential. The three shapes can help make things like rugs that can be remade, and reinvented through time…"(Company C13, Interviewee 13A-Founder & Owner, transcript page 37).*

"….We have created [Name of Product], a new range of carpet tile with around 50% less yarn than conventional carpet. Yet this has not sacrificed performance… TacTiles system means carpet tiles can be fixed in position ***without using liquid glue, almost banishing the environmental footprint*** *of the adhesive used in traditional carpet tiles…* ***creative thinking can change the way we do business and move us closer to the ultimate goal of being a restorative enterprise****" (Company C10, Interviewee 10A- Sustainability Director, transcript page 32).*

"The company's past practice had been to mix waste materials but, during a visit to the waste management company, staff were surprised to learn that a wide range of the materials could be recycled and were of potential value…The swarf from different metals had previously been mixed together, contaminated with coolant fluid and, as a result, the company received the lowest possible price for it. The company attempted to engage in conversations with the scrap merchant to discuss how the processes could be improved but to no avail… we eventually entered into dialogue with another metal recycling company and after obtaining an understanding of the recycling process and the quality of materials needed… The ***company designed a system that would keep all metals separate and which used gravity to separate the majority of coolant from the metal swarf****. The resulting segregated "dry" waste metals could thus be recycled back into higher specification metal with an enhanced value. The standard approach of using centrifuges to separate the swarf from the coolant was dismissed as being unnecessarily energy-intensive, when discipline and time could achieve the same ends...* ***finding solutions to environmental problems using such an creative approach****"(Company, C07, Interviewee 7A – Engineer, transcript page 23).*

*"We have been able to use our experience gained over the years by trial and error to learn to find solutions to problems****…. Solutions that is not immediately obvious*** *and involving ideas that may not be obtainable by using only traditional step-by-step logic… the most innovative and creative ideas come from our shop floor machine operators and engineers…come up with ideas to do things better… by challenging and motivating them to improve…Activities such as internal competition, training, opportunities to brainstorm and share ideas to improve resource use, working in partnership with universities on projects, visiting other industries has helped create the* ***ability for us to find new ways of doing things****… Solutions from co-workers that improved the company's operations were standardized throughout the organisation and the employee rewarded… Shop floor operators are equipped and supported to put forward new solutions to top-level management….* ***we have found mechanisms to catalyze and reward creative action for improvement****." (Company C26, workshop participant, transcript page 76).*

"By ***looking at innovation through the creative lens*** *of sustainability, we're able to deliver a portfolio of products and services with maximum performance and minimal impact on the environment…****The team works to rethink*** *materials, methods of make, products and business models* ***to solve complex sustainability challenges****…. I am huge believer in* ***collective intelligence*** *and diversity of thought…to me creativity is born out of* ***bringing people with very different approaches to problem solving with different insights together and solve it together.*** *To me it's all about how do* ***you unleash the creativity in teams*** *and in people by having them focus on things that make them passionate…****The creative thinking enabled us to come up with [produce name] a shoe that is really disruptive****… Created from knit threading rather than multiple layers of fabric. The old model involved cutting rolls of prewoven material into pieces, and then stitching and assembling them. But with* ***[produce name]****, a shoe's upper and tongue can be knit from polyester yarns and cables, which gets rid of all the unnecessary excesses, it required a complete creative rethink of the manufacturing process…The result is a shoe that's more environmentally friendly and could reduce long-term production costs…[produce name] has* ***35 fewer pieces to assemble*** *..The innovative process has already proven to be a* ***game changer, reducing waste of the [produce name] upper by some 80% compared to traditional running footwear****…We're reimagining the upper, the bottoms and the whole shoe. In addition, as materials such as rubber become harder to come by because of overharvesting or climate change, we're going to be able to navigate the volatility of these resources.." (Company C19, Interviewee: 19A- Director Sustainable Business & Innovation, transcript page 53).*

6.3.2 Discussion sub-theme A2 (ability to creatively reduce environmental and social waste)

Creativity and the ability to search for new ways of doing things that is not obvious is a strong pattern that emerges from the data across 11 companies. Interviewees in companies for example C10, C12, C15, C19, C26, and C20 spent extensive periods of time explaining the importance of 'creative thinking' and describing how they went about gaining the ability. Company C26 for example described, "*each time we try, we get better, even if we do not get the result we are looking for, this* ***ability to experiment helped develop this creative ability****"*. The data suggest 'learning by doing' being an **essential part of the ability** to develop the creativity ability.

Company C26, C01 for example described how by challenging and motivating staff and creating a culture in the organisation to learn to do more with less, the organisation was able to **find new ways of doing things.** Companies such as C01 have first focused on challenging their engineers, operators and employees to improve and squeeze everything out of the factory creatively i.e. reduce the energy it uses to manufacture one car by 77% with negligible capital investment. Company C01 is found to have done the efficiency improvements by focusing of using creativity to find solutions to reduction waste, then have invested in technology improvements after. It is interesting that some of the solutions implemented by the companies are not always by the use of cutting-edge technologies but instead clever thinking and creativity. For example Company C20 aerial-dry their jeans instead of using the traditional industrial dryers (refer Appendix 1, Figure 12- Aerial drying jeans), C07 used gravity to separate the majority of coolant from the metal swarf waste, C13 used creativity to make products with off cut waste that was going to landfill. The evidence confirms it is possible to produce more value with fewer inputs while maintaining the same or better quality (Company C10), through an enhanced creative ability.

Creativity is described to be an essential element of problem solving (Mumford et al., 1991; Amabile, 1996; Scot et al., 2004; Shrivastava and Statler, 2012). Authors such as (Lozano, 2011; Shrivastava and Statler, 2012; Rifkin, 2014; Hoque et al., 2014) recently have started highlighting the importance of organisations responding to environmental sustainability challenges with creative innovations; which help

conserve and improve natural, social and financial resources. Rickards et al. (2008) states although creativity is considered to be a vital ability, which must exist in and across all organisations, knowledge about creativity is highly fragmented. Scholars and practitioners from different fields such as psychology, arts, management, innovation, and engineering have kept their understanding of creativity within the boundaries of their particular practice or research disciplines. Authors such as Lavery et al. (2014) in the report 'the new industrial model' provide evidence of organisations being able to do more with less and improving non-labour resource efficiency in creative ways. The report highlights how creating more sustainable products, services and business models differ from regular innovation. Hoque et al. (2014) in the book "Everything connects: How to transform and lead in the age of creativity, innovation and sustainability" states that we live in a time where whole industries are displaced by other industries, staying ahead requires not just making the same thing a little bit cheaper, but making an entirely different product that delivers better value. The authors Hoque et al. (2014) describe how the more we understand the mental and emotional causes of innovation and creativity, the better we can lead ourselves and our team to make progress that matters.

But very few authors talk about creativity as an ability of eco-efficiency; Lozano (2011) describe creativity and organisational learning as means to foster sustainability. Ramus and Steger, (2000); Shrivastava et al., (2012) are some of the few authors that discuss the specific relationships between creativity and sustainability; the authors suggest creativity can help to catalyse the envisioning and implementation of new production processes and structures, and lead to improved quality, efficiency and safety for workers, consumers and the eco-system on whose health which we are all dependent. In these perspectives, creativity is a catalyst for innovation of products and services, as source of resources and improved energy efficiency, and as a foundation for sustainable policies and practices (Gupta, 2013; Shrivastava et al., 2012). Ramus (2000) proposes the environmental sustainability of businesses depends largely on employees' creative environmental ideas and innovative solutions to environmental problems. The author describes that supervisors who are open to new environmental ideas, experimentation, and innovative approaches to problem solving are good at encouraging employee eco-innovation.

Robèrt et al. (2002) describes that 'creativity within constrains' can help to engage people in creative process. The evidence from the case studies (example C20, C07) suggests companies have been able to look at a particular underperformance or problem and use creativity to rethink solutions.

44% of the companies interviewed gave examples of how they have used this creativity ability to find solutions; Company A08 for example describe, "*We hadn't looked at our factories in this way before…"* Most manufacturers described fostering the ability to creatively reduce non-labour waste a challenge in their organisation i.e. this is different to improving labour productivity, or equipment productivity which companies have developed the ability to do over the years and many examples and training exists. The ability to creatively reduce non-labour waste on the other hand is about finding answers that are not so obvious to other people. For example Company C20 state "*We also **aerial-dry our jeans,** our competitors don't do most of this…why use electricity and an industrial drier to generate heat, when the surrounding temperature is 35^{o}c…ingenious thinking and thinking out of the box helped us find these solutions".* Interestingly the data suggests solutions are not always found by looking at competition or industry leader and implementing industry best practices, creative thinking is an essential ability.

The data from the interviews companies C01, C20, C07, C13 for example suggests that by using the creativity ability manufacturers are attempting to tackle the environmental and social impact and inefficiencies in their system. The data also suggests manufacturers often don't need new technology to begin with (Company C01). It is observed that significantly better industrial performance is possible through creative thinking and careful planning without relying on the development of a 'step change' (Companies C01, C20, C07). The data supports the argument that the creative thinking ability aids companies to find solutions that are sometimes not immediately obvious. Company C19 described how the creative thinking ability enabled it to come up with a shoe with a reduction in waste of 80% and which has 35 fewer pieces to assemble. The data supports the argument that companies using the creativity ability are able to find 'factor 4' or more improvements in efficiency. This evidence strongly supports the authors' view that the 'ability to creatively reduce

environmental and social waste' is a key ability (i.e. sub-theme) of efficiency in industrial sustainability.

The evidence from across 11 case companies confirms the sub-theme A2 'ability to creatively reduce environmental and social waste' is one of the key ability of eco-efficiency. Bringing the data together the author therefore proposes to define the sub-theme A2 as **'ability to *find creative solutions for the environmental and social waste***"

Sub-theme A3

Using a variety of terminology such as 'sharing information', 'continuous improvement', 'standardise', 'shared vision', 'setting targets', 'fundamental minimum', the author has identified and proposes the theme A3 – **ability to systematically reduce environmental and social waste**, which is explored in this section**.** The data across the 26 cases suggests these abilities have helped the case companies identify improvements in a systematic way and to take action and make it a routine activity in their organisations.

Data on Sub-theme A3 - ability to systematically reduce environmental and social waste

*"top-management **empower and supported 'champions'** for initiating projects for improvements…technique helped develop a disciplined and effective approach for **everyone in the organisation to engage** and bring forward ideas for improvement collectively… the challenge is **cascading the learning from one employee to another**… setting an environment for peers to work in mixed groups helped transfer the knowledge…**Routine environmental training activity** help improve general employee awareness…* **regular *training and discussion*** *is a key feature, with staff empowered to identify and solve problems themselves…..visual communications boards and visiting other manufacturers from different sectors for lessons, training frontline supervisors to provide employees with environmental information…**ensuring and carefully developing routines** for brainstorming ideas and implementing them...motivation from top management was key for starting the journey…this brought a new culture and capability and more importantly a **shift in mindset** in the organisation, where shop floor staff were motivated to go find new ways of doing things better that resulted in economic, environmental and social benefit…employees came up with projects such as the delivery truck sharing initiative with neighbouring companies, innovative use of grey water for daily use, energy monitoring and control systems, over 40% reduction in packaging off-cut waste… this approach helped **us identify improvements in a systematic way**.. What we have been trying to do is, raise awareness at all-levels and empower our employees to take action to change for the better**... its about day-to-day behaviour and creating that mind-set is key…** an openness to change and willingness to look beyond the status quo has been important**…. systemised problem-solving is an on-going challenge…in-house continuous improvement managers and sustainability teams address resource efficiency challenges.**. Passionate leaders who can motivate the entire workforce has been important**…becoming systematic** relies on continuous development and a focus on willingness to learn, innovation, facilitated by employee participation and creativity…"(Company C26, workshop participant, transcript page 76).*

*"…. **(Routine)** Promote the idea that anybody within the organisation is able to **contribute through kaizen and promote innovation**…**(Vision) -** A Core philosophy for all members…. Success is often founded on very clear vision and consistent implementation, the (Company C01) 2020 vision, Earth charter issued in 1992, EU environmental policy, ultimate eco factory vision, helped guide everybody in the same framework.. to take people along with you, you have to create a vision. But the vision also has to have certain levels of attainability within it.. We're at position A and position B is over there. Are we going directly towards B, We don't truly know. But as long as the vector is taking us in the right direction, we will make that step and move forward" (Company C01, Interviewee 1A- General Manager for Environmental Affairs and Corporate Citizenship, transcript page 3).*

*"Some techniques we use are **promote effective inter-company learning**…two plants generation 1 and 2**,** architecture is completely different… We wanted plant 1 to compete and catch up with plant 2. And plant 2 to push on new boundaries…One has been working on energy and the other on water… Those were the big challenges at those plants...We instituted a competition using a racing track to plot out the performance of the 10 different shops in the production plant: Paint, Assembly, Power Train, Body Welding, etc. Once a month, the performance of each shop is plotted out on the racetrack, so shop captains can see how they are doing... Instituted a process where experts from one facility examine improvement options at other plants...**The key is we share the various different bits of information we are gaining across the organisation.**..to perform effective **Yokoten (sharing)** you need a certain number of things.. We need a **network, a forum/opportunity, mechanism/standardized format, motivation and recognition**.... we have 51 manufacturing companies in 27 countries…Have to create an opportunity to share (Forum/opportunity)…we have a Global environment conference, 5 regional so **we can share ideas**…We also have a **Shop by shop activity to develop new ideas and actions** (e.g. paint shop).. Where each of the shops will get together from 4 manufacturing sites in Europe that have a paint shop…We will put 4 of the groups together…Give them a leader, **they will share information** that is specific to their processes…learning across different manufacturing sites is very important…we have set up a 'teach-learn-do-teach' approach, where in return **for learning from one factory site, employees need to teach another factory site about what they learned,** which encourages cross-factory learning…One tool we use to share the knowledge is our own eco-handbook..the handbook has many detailed chapter covering the processes commonly found … **booklet and intranet systems provide a hook..** employees will take it away and contact the right people, plan a visit to go and see...**these activities help us systematically identify waste and achieve a culture of continuous improvement…**We want to be **able to improve the performance of older plants and take the newer ones onto a different level"** (Company C01, Interviewee 1A- General Manager for Environmental Affairs and Corporate Citizenship, transcript page 4).*

*"Sustainability and **the delivery of systemic change** …developing a clear plan to turn a huge number of stakeholder views into a series of steps the business can follow to head in the direction of sustainability was important…[Name of change program] in essence is a massive change management programme….[company] **has always insisted that it is aiming to deliver systematic change through the initiative..** It's changing every aspect of how we do business... **How we develop and source products; recruit, retain and reward people; interact with our customers; run our lorries and stores...** We will only become more sustainable by helping people change, whether as customers, employees, suppliers or investors hearts and minds…**we have built a business case that rewards us for the progress we are making.."**(Company C03, Interviewee 3A- Director of Sustainable Business, 3B- Head of Sustainable Business, transcript page 11).*

"....The energy target setting process is a structured, phased ***programme bringing internal and external experts together to share information****. Experts work on performance, installation and general design of manufacturing infrastructure to optimise energy and water use and use recovered material. The first step involves a team* ***gathering energy and water data****. This data is used to* ***brainstorm new projects*** *with the potential to make energy and water savings. These are* ***prioritised*** *and then undergo detailed* ***cost-benefit studies****. An* ***action plan is created and agreed****...****We've got six pillars within the model: energy, water, waste, biodiversity, value chain and, most importantly, people and community****. **We identified early on that different things float different boats for different people**... So instead of having an overall environmental message for everyone to buy into, we have those individual pillars with an aspirational ambition against each one...* ***This allows individuals to tailor their preferences,*** *so if someone is particularly interested in biodiversity, for example, they can really get hold of that. Someone else may be much more interested in energy so they can work on that instead..."(Company C05, Interviewee 5A- Sustainability Manager UK, transcript page 17).*

"We need this open to ***lateral thinking*** *e.g. that's a good idea we saw over there, but* ***how do I apply it over here, they don't have the same conditions****. So you need some lateral thinking" (Company C01, Interviewee 1A- General Manager for Environmental Affairs and Corporate Citizenship, transcript page 5).*

"Champions and employees are empowered to find efficiency and waste reduction improvements continuously...(waste nothing culture)...the culture of doing more with less is reinforced with employee suggestion and reward schemes ... *employees across the organisation identify efficiency improvements and systematically eliminate waste continuously.... We encourage sharing of best practices across group companies..* ***(company name) has systematically identified ways to turn waste streams and emissions from our sugar production processes into useful and positive inputs to new product lines"*** *(Company C02, Interviewee 2B- Head of Engineering, transcript page 8).*

6.3.3 Discussion sub-theme A3 (ability to systematically reduce environmental and social waste)

Most companies described the importance of effectively and systematically sharing information gained from doing the environmental and social improvements across the organisation. Companies C01 and C26 described specifically the importance of transfer of knowledge and practices from one operator to another being important and inter-company learning. Company C26 described the challenge of cascading the learning from one employee to another.

Continuous learning through routine environmental training and awareness programs and learning from experts and colleagues was described by over 83% of companies as

being important in developing general awareness. Company C01 described the importance of creating an opportunity to enable sharing. Interviewee A1 described *"a lot of your success comes from bringing people internally along the journey with you". Company C20 described "Raising awareness across the organisation through education and training by developing a platform for learning and sharing lessons… providing staff with skills, knowledge, tools is important for becoming systematic"*. Companies C26, C20, C01, C03 for example described environment training, frequent communications, standardization, inter-organisation learning as all being important to the development of a systematic approach to identifying inefficiencies and improving performance in their organisation. Company C01 described techniques the organisation use to promote effective inter-company learning "*two plants, generation 1 and 2, architecture is completely different… We wanted plant 1 to compete and catch up with plant 2. And plant 2 to push on new boundaries…One has been working on energy and the other on water… Those were the big challenges at those plants"*. Company C01 described *"we have set up a 'teach-learn-do-teach' approach, where in return for learning from one factory site, employees need to teach another factory site about what they learned, which encourages cross-factory learning".* Company 26 described the importance of fostering an environment and culture that encourage learning, where internal groups are able to share ideas and learn from one another being important in their journey to becoming systematic at finding improvements.

The use of techniques such as the waste hierarchy, 5-Whys for root cause analysis, Deming cycle (plan–do–check–act), visualization using fishbone diagrams for identifying possible causes for an effect, was described by many of the companies (example C05, C26) as techniques and methods used internally in their sustainability teams to brainstorm, identifying, prioritising and communicating improvements. The use of the tools was described as aiding in the organisations ability to find and analyse and reflect on possible root causes to the environmental under performance and identify improvement opportunities.

Interestingly 82% of the companies interviewed directly referred to the importance of 'shared vision' in their journey towards becoming systematic at identifying waste. Company T01 for example explained how a clear vision helped the organisation take

steps and move forward in the right direction. Most companies described in specific a vision with a long-term goal, with challenging and ambitious targets was important. For example companies (C01, C26, C05, C03) described how challenging targets encouraged their employees to become effective at identifying waste and strive towards the long-term goal.

Over 90% of the companies stated top-management commitment was key. Company C26 described how top-management commitment brought a new culture and capability in the organisation where shop floor staff were motivated to go and find new ways of doing things better.

Only two experts (interviewee 18A, 1A) described the concept of fundamental minimum. Though this concept was only emphasised by two experts, the researcher was convinced this is important from the evidence gathered; Interviewee 1A, described "*If we were to take water from ambient temperature to 100 degrees to make it boil, that volume of water would need a certain amount of energy to take it through that process – any additional energy you put into that bottle of water to raise the temperature from your supply is waste. When you know what your minimum is – that is the true target. It is a different approach to simple benchmarking… We call it Gentani – to understand the real minimum resource that you need to carry out a process"* (Company C01). Interviewee 18A describes for example *"How much paint does it take to cover a door? the engineering specification might suggest a very clear minimum: the thickness specified, multiplied by the surface area. This provides a minimum that suggests how far things could be squeezed in an ideal world. Evidence suggests that no factory is approaching its fundamental limits and that understanding and using the idea of fundamental limits is a useful concept for driving the performance of a particular system. Setting challenging and ambitious targets seeking the ideal can unleash the creativity of your engineers to achieve something great".* This concept is argued to challenge employees to explore systematically ways in which the ideal might be approached and encourage innovation that unlocks sustainability improvement.

The numerous case study examples and literature demonstrate the benefits in implementing sustainable manufacturing practices (Lovins, 2011; Rusinko, 2007; Seliger et al., 2008, Menzel et al., 2010). However, the adoption of sustainable manufacturing practices is not systematic (Madsen and Ulhoi, 2003; Despeisse 2015). Glover et al. (2011) states kaizen events have been widely reported to produce positive change in business results and human resource outcomes. Their research identifies the factors that most strongly influence the sustainability of work area employee attitudes and commitment to Kaizen events based on a field study of 65 events in eight manufacturing organisations. The energy and waste hierarchies (Sarkis, 1995; Lund, 2007; Dovì et al., 2009; Blackstone, 2011) provides a structured approach to prioritise tactics by identifying at which stage an improvement should be implemented. Despeisse et al. (2013) propose a combination of tactics, factory modelling and improvement hierarchy to understanding the methodical improvement opportunities. Litos and Evans (2015) seek to understand how eco-efficiency can be captured as a systemic quality with transferable properties across manufacturers, but do not discuss an ability-based view. (Despeisse et al., 2013; Litos and Evans, 2015) are some of the few authors that present a novel approach to systematise the identification of improvement opportunities in factories, tactics for improvement and best practices. However none of the above researchers present an ability-based view.

Over 72% of interviewees repeatedly stated the importance of gaining the 'ability to systematically reduce environmental and social waste' and described the challenges and how they go about developing the ability. Evidence was found on companies being able to share best practices across sites to promote inter company learning, being able to develop routines, being able to standardise practices, being able to develop a shared long term-vision, being able to set challenging environmental and social targets, being able to find the fundamental minimum, being able to solve problems using lateral thinking, being able to develop the ability to identify root causes being important in in developing the ability to systematically remove waste.

The evidence strongly supports the authors' conclusion that A3 is a key ability (sub-theme) of efficiency in industrial sustainability. The sub-theme A3 'ability to systematically reduce environmental and social' waste is a confirmed theme of the

efficiency (Theme A). Bringing the data together the author defines the sub-theme A3 as **the ability to identify improvements in a systematic way and make it routine.**

The sub-theme A1 (the ability to see environmental and social waste) and A2 ('ability to find creative solutions for environmental and social waste') and A3 (the ability to identify improvements in a systematic way and make it routine) is therefore a confirmed theme of efficiency (Theme A).

⇒ Bringing the data together the author proposes to define the theme A as '**ability to see environmental and social waste and creatively and systematically reduce them'**

6.4 Summary of findings from the efficiency ability

Bringing the findings A1, A2, A3 together the author defines the efficiency ability as;

Efficiency theme (A)- ability to see environmental and social waste and creatively and systematically reduce them.

- **Sub-theme (A1)- ability to see environmental and social waste**
  - Being able to see waste,
  - Being able to be physically present at the location.

- **Sub-theme (A2)- ability to find creative solutions for environmental and social waste.**
  - Being able to experiment,
  - Being able to learn by doing.

- **Sub-theme (A3)- ability to identify improvements in a systematic way and make it routine.**
  - Being able to develop routines,
  - Being able to share best practices across sites,
  - Being able to standardise practices,
  - Being able to develop shared long term-vision,
  - Being able to set challenging environmental and social targets,
  - Being able to find the fundamental minimum,
  - Being able to solve problems using lateral thinking,
  - Being able to develop the ability to identify root causes.

Chapter 7
Analysis of Internalisation ability (Theme B) descriptive stage

This chapter presents the findings from the second stage of the research. The aim of the chapter is to explore in-depth and identify the sub-themes that comprise theme B (Internalisation). New data are used to elaborate on the theme, while adding new sub themes and findings to the theme. The findings are compared against the existing literature to show it adds new detail and contributions to knowledge.

7.1 Internalisation (Theme B) - current understanding and existing knowledge:

The internalisation theme proposed by the author refers to evidence and observations found on the **ability that allows companies to deliberately bring activities and value into the business model that others leave outside**. Some of the value uncaptured is visible, e.g. waste streams in production, co-products, under-utilised resources; and some is invisible, e.g. over capacity of labour, or service.

Internalising the negative externalities of business is an important theme in industrial sustainability. Smith et al. (2010) states environmental considerations are poorly served by existing markets because costs and prices fail to internalise environmental externalities, and consequently fail to generate effective demand for cleaner innovations. Hart and Milstein (2003) state that seeking to reduce the negative impacts of business is clearly an important step, but firms ultimately need to go much further, and proactively seek out new value creation opportunities to deliver novel solutions to social and environmental problems that begin to address the wider sustainability challenges directly. Some organisations externalise the negative impacts of business (e.g. environmental degradation and pollution or undesirable social

impacts). It is argued this is because ecological systems and natural capital required for human welfare are not explicitly valued (Costanza et al., 1997). One of the key challenges is designing business models in such a way that enables the firm to capture economic value for itself through delivering social and environmental benefits (Schaltegger et al., 2012).

There is a growing literature studying those business models that seek to internalise environmental costs. For example by encouraging business models that focus on re-manufacturing and re-use, and avoid dissipation of polluting or harmful substances (Foresight, 2013). An encouraging study carried out by WRAP has shown there is a great opportunity for businesses to repair and re-sell home electronics. Waste from electrical and electronic equipment (disposed of via household waste recycling centres) is estimated to be worth £200 million in gross revenue per year (WRAP, 2013). Freeman et al. (2010) describe stakeholder value as being either positive (a benefit) or negative (an impact, or destroyed value). The business model literature tackles a central concept for all businesses, which is most commonly referred to as the value proposition, representing the positive benefits delivered to its stakeholders.

Key authors such as (Richardson, 2008; Chesbrough, 2010; Teece, 2010; Osterwalder and Pigneur; 2010; Zott and Amit, 2011; Bocken et al., 2014) have contributed to the literature on business models and business model innovation and more particularly, have described potential business modelling processes. There appears to be reasonably good conceptual understanding of business models, albeit, with several differing perspectives (Teece, 2010; Zott et al., 2011). Teece (2010) describes that the essence of a business model is in defining the manner by which the enterprise delivers value to customers and entices customers to pay for value (i.e. finding out what customers want and how they want it), and converts those payments to profit (i.e. the organisational activities to meet those needs and make a profit).

The ‘business model canvas’ is a popular framework to support the generic business modelling process, developed by Osterwalder and Pigneur (2010). Osterwalder and Pigneur (2010) describe the following elements of a business model: customer segments and value proposition (value proposition), channels, customer relations; key resources, activities and partnerships (how to create value); and revenues streams and

cost structure (how to capture value for the firm). Zott and Amit (2010), present the business model from an activity system perspective, viewing the business model as a network. This exemplifies an emerging view that business models need to be developed with a network rather than firm-centric perspective. While being well-conceived and academically grounded, its ability to generate innovative thinking beyond pure economic value creation seems limited due to the narrow view of the value proposition focusing only on the customer.

The literature currently fails to provide evidence on abilities that organisations are using to internalise these negative externalities of business and capture new value through business model innovation. Some frameworks exist (e.g. Rana et al., 2013; Bocken et al., 2014; Yang et al., 2014; Holgado et al., 2015) but whilst each adds understanding to the process, they do not seek to provide an ability-based view. Abilities that enable firms to systematically look for different forms of value uncaptured is not discussed in the literature.

The author has had the fortune to have colleagues working on the problem of sustainable business model innovation and has been heavily influenced by the language used, specifically the concept of failed value exchange (Rana et al., 2013; Bocken et al., 2014) has informed the analysis in this research.

In the following sections the research data is used to elaborate on this ability through the lenses of sub-theme.

7.2 Findings of new sub-theme of the internalisation (B1, B2)

This section presents new or additional understanding on the ability of internalisation; this includes emerging sub-themes that are described and evidenced.

7 out of 26 case companies described how they have been able to improve their ability to see failed value exchanges (i.e. missed/uncaptured value opportunity; negative social impacts, environmental damage, depletion of non-renewables). It is observed some organisations through experimentation and through experience of tackling efficiency improvements, whom did not deliberately set out to find failed value, yet

by maturing in their ability to ‘see wastes’ and tackle eco-efficiency improvements initially, they have been able to find failed value in their system and have been able to deliberately bring activities and value into the business model that others leave outside. The data suggests that organisations which have been ‘able to see failed value’ in their system have been ‘able to capture some of that failed value’ (e.g. heat loss into the atmosphere) and have been able to find opportunities to internalise it to form positive value for the business, planet and society creatively (i.e. generate solutions that capture new value through the reduction or elimination of failed value). The author has grouped these findings and chosen the sub-themes as (B1- ability to see failed value exchanges) and (B2- ability to creatively transform failed value into positive value and bring them into the business model) as a probable ability, which is explored in this section. Value here is interpreted as the different forms of failed value exchange, for example waste streams in production, wasted heat and under-utilised resource.

Data on sub-theme B1 (ability to see failed value exchanges) and B2 (ability to creatively transform failed value into positive value and bring them into the business model).

The following quotes bring out both sub-themes and illustrate some of the challenges in decomposing an integrated ability.

"We are the world's largest refinery producing 420,000 tonnes of Sugar annually…We been able ***to find opportunities in our process to produce co-products from the waste streams of the primary sugar production processes****… (Symbiotic co-product lines)….We have found a broad range of additional synergistic and profitable product lines… animal feed, electricity, tomatoes, and bioethanol….More than two hundred and forty miles of piping carries hot water from the factory's Combined Heat and Power (CHP) plant around the glasshouse, to maintain the balmy temperatures, which suit tomato plants.* ***This hot water would otherwise be destined for cooling towers, so the scheme ensures that the heat is used productively…. carbon dioxide as a by-product from the CHP boiler is pumped into the enormous glasshouse to be absorbed by the plants (rather than vented into the atmosphere as waste emissions)….****waste carbon dioxide from the factory is used by tomatoes for photosynthesis… the site also harvests the rainwater from the giant glasshouse roof; over 115 million litres are collected annually to irrigate the plants…the horticulture business produces around* ***140 million 'eco-friendly' tomatoes each year…co-product generated by finding opportunities for productive, and creative use of the waste streams….****The heated atmosphere of 4 times ambient levels of CO2 enables the tomatoes to grow at twice the usual rate, providing high productivity for the glasshouse investment. "(Company C02, Interviewee 2B- Head of Engineering, transcript page 8)*

*" [Company X] have teamed up with us [Company Name] denim factory to launch a new collection of sustainably made shoes…****The shoe uppers are made from off-cut denim trouser waste that would normally have gone to waste****... Through this initiative we are able to* ***give back to the community****… 100% of the profits from this initiative go to the orphanage…* ***the company, planet and society benefit****… We* ***saw an opportunity*** *to demonstrate the big idea of one thing being re-cut* ***into something new without there being any waste*** *and* ***create more value*** *…The orphanage is home to approximately 136 children from newborns up to 16 years old. The profits will be used to provide education, meals and medical care for the children." (Company C20, workshop participant, transcript page 55)*

"We have learnt to understand where the value exchanges fail with all six primary stakeholders; the People – separated into Customers, Suppliers, Staff and Society – Planet and Profit, ***…..Look at what value exchanges are failing between these six and you see a lot of value opportunities****… For example, this group want X but they are not getting it,* ***which provides a business for another group.*** *Another group doesn't want Y but we are giving it to them, so* ***why are we over-delivering****?…." (Interviewee 18A- Director Centre for Industrial Sustainability, transcript page 51)*

"The factory ***turns sweet waste from the manufacturing process into a 'chocolate soup'****. This 'soup' is then fed into an airtight tank, the anaerobic digester, where bacteria decomposes the material and* ***converts it into the useful by-products - clean water and biogas****….the* ***system allows us to convert a large amount of waste that would otherwise enter sewage, or be sent to landfill*** *where it would generate methane and other greenhouse gas emissions…. the factory has* ***found a way of converting four tonnes of solid waste and 200,000 litres of liquid waste into renewable energy and clean water each day****…The anaerobic digester produces enough biogas to fuel a 200kw CHP engine which creates 4.8MWh of electricity a day - around 8% of the sites total consumption…."(Company C05, Interviewee 5A- Sustainability Manager UK, transcript page 17).*

"I've been passionate about waste for years, I want to add value to waste and build a valuable product from it…The adventure started on an auditing course to learn more about ISO 14001 the environmental management standard, where I met members of the [Company Name]. They told me about their disused fire hoses, which cannot be traditionally recycled. I ***asked to see some*** *and they took me to their fire hose assessment site…There were coils and coils of it piled on the rooftop... landfill is completely inappropriate end for such a heroic material…****Some might struggle to see how old*** *fire hoses* ***could be beautiful****, but When you polish it and see the lustrous red rubber* ***it becomes this fantastic material****…****taking all of it and transforming the*** *fire hoses* ***into something that could have a second life at least as long and useful as its first was the goal…****the fire hoses was designed to survive fires and was waterproof, all of which make it a great alternative to leather****...we decided that the products we design too must be built to last...we used our*** *imagination to find sustainable ways to rescue the decommissioned fire hoses,* ***we figured out what we could make from it****…****If a use couldn't be found*** *for the fire hoses* ***most of it would go to landfill****…. **we been experimenting** fire hoses for a while…****months of experimenting to figure out how best to manipulate and re-purpose it****...A* ***lengthy process of trial and error ensued****…we made the fire hoses into roof tiles, furniture, Christmas ornaments… and finally belts…today the designer crafted belts, bags, and accessories are sold in the world's most luxurious department store..* ***50% of all profit from sales is donated to charities associated with the wastes used****" (Company C13, Interviewee 13A-Founder & Owner, transcript page 38).*

"This way of thinking about value – we been able ***to find opportunities to capture failed*** *value… water entering the business would leave as a 'waste' but we can clean it to a level that can be bottled for drinking. (Company C20, workshop participant, transcript page 55)*

Interestingly the data from across case companies for example C02, C05, C20, C11, C13 suggest some of the organisations that have been able to develop and become effective at using the efficiency ability, are shown to be using that **ability to now see failed value exchanges in their system.** The below section discusses the sub-theme (B1- Ability to see failed value exchanges).

7.2.1 Discussion sub-theme B1 (ability to see failed value exchanges)

The data suggests the company C02 for example a leader in efficiently and sustainably manufacturing sugar beet, over the past three decades has been able to **systematically find failed value exchanges in their system**. Company C02 described, "*We **routinely** seek innovative ways to minimise waste and maximise value".* The company has been able to see 'carbon emissions' and 'low-grade heat' escaping from its processes into the atmosphere as a failed value (a by-product from the CHP boiler). Company C02 described, "*this hot water would otherwise be destined for cooling towers…we identified that our supply of carbon dioxide, heat and water **could be better exploited if we used it again**."* The company has been able to identify the waste streams (i.e. carbon dioxide, heat) that had value that is not being captured and destroyed in its system (i.e. failed value).

The data suggests that company C05 has initially been able to see the 'sweet waste' as a by-product from the manufacturing process that was being sent to landfill as a failed value. The company has be able to identify the waste by-product had more value that was not currently being captured and destroyed in its current system. Company C05 described *'the system allows us to convert a large amount of waste that would otherwise enter sewage, or be sent to landfill where it would generate methane and other greenhouse gas emission'*

The company C20 was able to firstly see the off-cut denim trouser waste (i.e. post-industrial scraps) that was going to landfill and downcyled as a failed value in its current system. The company was able to see the off-cut waste could be transformed into something else more useful and valuable, which is not captured, and create positive value. Company C02 described, *"the off-cuts would normally have gone to waste…. We saw an opportunity to demonstrate the big idea of one thing being re-cut into something new without there being any waste and create more value."*

The company C13 the data suggests was able to see the *fire-hose* that was going to landfill as **valuable material** that had more use that is not captured and missed as **a**

failed value of that system. Company C13 described *'**Some might struggle to see how old** fire house **could be beautiful.**..but When you polish it and see the lustrous red rubber **it becomes this fantastic material**… **taking all of it and transforming the** fire hose **into something that could have a second life at least as long and useful as its first was the goal'.***

The data suggests the '**ability to see failed value exchanges'** being an important step. Most of the companies described 'being able to see failed value' in their organisations **difficult and challenging**. It is described this is due to, some of the failed value being more **easily visible** such as waste streams in production, co-products, and under-utilised resources; while some others **not easily visible** such as over capacity of labour, insufficient use of expertise and knowledge. Most organisation found seeing failed value exchanges being an important ability to uncover new value opportunities in their current system; Company C26 in a workshop to identify failed value types in their organisation and network of stakeholders described ***"being able to see these types of failed value exchanges helped our company find new opportunities** and its fantastic. It has helped us think differently and broader…**. Getting everyone in our organisation to be able to do it is going to be a challenge and an interesting journey and learning**...We have learnt we need to empower our employees to see these different types of failed value in our system and processes, get them **to think differently** and be **more aware of these opportunities we currently don't pay much attention towards**…We need to create a space for them to be able **to experiment and pilot and challenge the current system** to capture these failed values and **convert it to different forms of higher positive** value…the collective learning by engaging everyone in this process will improve our understanding of this and develop this ability."*

In the analysis of the data from the case studies, failed values types are identified in this research and proposed by the author;

- **Type A: I give, but don't get a return** (e.g. Company X gives cleaner water after production, but does not get a return)
- **Type B: I give but you don't want** (e.g. company X gives carbon dioxide and heat to the planet and neighbours that they don't want)
- **Type C: I don't give but you want** (e.g. Customer X wants longer lasting and durable product but is not getting it from Brand Y. A business might be missing an opportunity to capture value.)
- **Type D: I have too much (or give)** (e.g. company X produces alot of by-product Y, this can captured and used for another process Z)

uncover new value opportunities. The data suggests that some organisation that are initially able to see the failed value, are then found to be able to capture failed value, creatively transform it to positive value and deliberately bring it into the business model. The below section discusses the sub-theme (B2).

7.2.2 Discussion sub-theme B2 (ability to creatively transform failed value into positive value and bring them into the business model)

The data suggests that company C02 for example has been able to turn waste streams (i.e. Failed value) and emissions from their core production processes into useful and positive inputs to new product lines. No material arriving into the company is allowed to disappear as waste (and a cost). Instead all materials are turned into valuable co-products. The data suggests that company C02 has been able to firstly identify failed values and then bring more value under its control by using and linking its knowledge to turn waste streams in its current systems into a valuable output and create positive value. The company has been able to see the combustion gases from the power station and low-grade heat as failed value lost to the atmosphere. The company described how it has been able to find away to capture the two waste streams and transform it to create new positive value (i.e. grow tomatoes) and deliberately bring it into the business model. By seeing failed value and bringing it into the business model, the company has been able to make productive use of waste carbon dioxide and heat from the sugar factory, which tomatoes (new co-product) use during photosynthesis. It is described the carbon dioxide (a by-product from the CHP boiler) is pumped into the enormous glasshouse to be absorbed by the plants, rather than vented into the atmosphere as waste emissions. It is observed the company has firstly been able to see the failed value exchange, and then figure out what to do with it to form positive value, and come up with a solution using its knowledge and control.

Company C13 described how it has been able to find opportunity to make luxury handbags and belts from waste an end of life product that would otherwise become landfill. The company C13 described *'we been experimenting with fire horses for a while…months of experimenting to figure out how best to manipulate and re-purpose*

it...A lengthy process of trial and error ensued…we made the fire horses into roof tiles, furniture, Christmas ornaments… and finally belts…today the belts, bags, and accessories are sold in the world's most luxurious department store. 50% of all profit from sales is donated to charities associated with the wastes used". It is observed the company has firstly been able to see the failed value (i.e. the hose going to land fill), then internalize it (i.e. deliberately bring it into the business model) and figure out what to do with it to form positive value, and then come up with a solution. The data suggests the company has first been able to see the failed value (i.e. that the end of life material is valuable material). The company initially described it didn't know what to do with it, but through experimentation, trial and error was able to innovate and find a solution (refer Appendix 3, Figure 16 - waste fire horse to designer bags).

Company C20 described how it has been able to undercover new value opportunities by transforming failed value to positive value and deliberately bring it into its business model. The company described " *We saw an opportunity to demonstrate the big idea of one thing being re-cut into something new without there being any waste and create more value …"* The company found away to capture its denim waste and create shoe uppers from off-cut denim trouser waste that would normally have gone to waste (refer Appendix 1, Figure 13 - Shoe uppers are made from off-cut denim trouser waste). The profit from this new business model is described to be used to build an orphanage that provides education; meals and medical care for the children. The company also described other opportunities *"This way of thinking about value - opportunities to capture failed value, has helped us for example think…where water entering the business which normally leaves as a 'waste' could be cleaned to a level that can be bottled for drinking".*

Interestingly the data from across case companies for example C02, C05, C20, C11, C13 suggest that some organisations have been able to find ways to capture the failed and **uncover new value opportunities.** The data suggests that some organisations using this ability are able to transform failed value to positive value. Organisations that have found failed value (i.e. see the waste) are **then found to be experimenting and innovating to find solutions** (i.e. don't yet know how to turn it into value). By **linking internal and external knowledge** some organisations are found to be able to

creatively capture positive from the failed value exchanges in its system and network of stakeholders. Company C02 for example has been able to create co-product lines (i.e. animal feed, electricity, tomatoes, and bioethanol etc.) from the waste of its primary product line sugar production. The 'opportunity thinking' culture coupled with the waste nothing attitude in the organisation, and those with the **process knowledge being empowered** to identify the innovations to be taken forward is described to aid the development of this ability. The company C02 has a full-time team seeking out new opportunities for co-product use. The team keeps **'exploring and looking for the best next way'** which is described by the company C02 to have aided the development of this ability.

Most organisation described the challenges of being able to uncover new value opportunities. Over 67% of the companies described even if the value failed is identified, it is hard to create value from it. Company C26 in a workshop to identify failed value types in their organisation and network of stakeholders described, *"many opportunities for synergistic value creation are unnoticed currently"*. Most of the companies described they may not be aware of the full range of value outcomes of their business operations i.e. business may be creating value in some form, but failing to capture value from the customer or society for this. Companies such as C02, C05, C13, C20 described they have been able to develop this ability over time through a culture of being able to **experiment and learn by doing.** Most organisations described being able to **encourage new ideas and supporting the implementation of new initiatives being important** to developing the ability to discover failed value.

Both sub-themes receive little clear attention in the literature, though many authors write about related concepts. The concept of value exchange is referred to in the Sustainable business models literature; include closed-loop business models (Wells and Seitz, 2005; Kraaijenhagen et al., 2016), 'Natural Capitalism' (Hawken et al., 2005), social enterprises (Grassl, 2012), Product Service Systems (PSS) (Tukker et al., 2015) and new economy concepts (e.g. Blue Economy; Pauli, 2010). A few authors have sought to unify the various examples in literature and practice in a useful categorisation under the over-arching theme of business model innovation (Boons et al., 2013). View of value that integrates social and environmental goals (Schaltegger

et al., 2011) and a multi-stakeholder perspective that addresses not only customers and shareholders but also society stakeholders (Holmes and Smart, 2009; Hart and Milstein, 2003) is suggested to be important. Very few authors have contributed towards understanding the creation of new systems and generating value across the value network in the sustainable business models literature by **identifying failed value exchanges**. Authors such as (Rana et al., 2013; Yang et al., 2013; Bocken et al., 2014) are the few authors that have contributed towards understanding opportunities for value creation. Yang et al. (2014) describe and define multiple forms of value (e.g. value absence, value surplus, value destroyed, value missed). Rana et al. (2013) and Bocken et al. (2014) in their research propose a framework for business model innovation for sustainability by explicitly considering **value destroyed and value missed within the business model**, as these often represent important opportunities for sustainability innovation. Their research provides a qualitative framework to facilitate systematic exploration of the different forms of value for each stakeholder.

- Value captured – current value propostion
- Value destroyed – negative value outcomes of current model
- Value missed – value currently squandered, lost or inadequately captured by current model
- Value opportunities – new opportunities for additional value creation and capture through new activities and relationships

Most of these authors are colleagues in a large research centre and this researcher acknowledges their helpful influence in his own analysis.

Rana et al. (2013) and Bocken et al. (2014) are some of the authors that come closest in their comments to describing failed value exchanges approach and providing an understanding to the concept of sustainable value creation and failed value exchange logic. Bocken et al. (2013) describe value destroyed can take various forms, but in the sustainability context is mostly concerning damaging environmental and social impacts of business activities (e.g. pollution). Missed value opportunities represent situations where individual stakeholders squander or fail to capitalise on existing assets, resources and capabilities or fail to receive the benefits they seek from the network. It is described this might be due to poorly designed value creation or capture systems, failure to acknowledge value, or inability to persuade others to pay for the

benefit. New value opportunities are described to help expand the business into new markets and introduce new products and services that offer enhanced benefits to stakeholders. Beyond customers, this might involve seeking to enhance employee wellbeing or making positive contributions to the environment. However, none of the above researchers present an ability-based view understanding towards seeing failed value exchanges in their system.

The data from across the cases (example C02, C05, C13, C20) suggests the ability to see and discover failed value exchanges in the system and its multiple stakeholders of the firm being important. Organisations developing this ability B1 are found to be able to capture and bring into their business models new positive value opportunities to create new economic (e.g. business), social (e.g. neighbours), and environmental (e.g. Planet) value from their business (i.e. multiple stakeholder view of value, a network rather than firm centric perspective). Being able to see and discover failed value exchanges is observed to be key to enabling opportunities for creating sustainable business models and innovations for positive value creation (i.e. new opportunities for value creation). Organisations developing this ability are able to deliberately bringing activities and value into the business model that others leave outside. This is observed to aid the identification of opportunities for internalising costs and transforming them to value, enabling creation of new business models and new value forms.

The sub-theme B1 (ability to see failed value exchanges) and B2 (ability to creatively transform failed value into positive value and bring them into the business model) is therefore a confirmed theme of the internalisation ability (Theme B).

⇒ Bringing the data together the author proposes to define the ability B as ‘ability to see failed value exchanges and deliberately bring them into the business model’.

7.3 Summary of findings from the internalisation ability

Bringing the findings together the author defines the Internalisation ability as;

Internalisation theme (B)- ability to see failed value exchanges and deliberately bring them into the business model.

- **Sub-theme (B1) - ability to see failed value exchanges**
  - Being able to see and discover failed value exchanges across the current system and the firms network of stakeholders,
  - Being able to discover failed value types in the network,
    - Type A (I give, but don't get a return)
    - Type B (I give, but you don't want)
    - Type C (I don't give but you want)
    - Type D (I have too much)

- **Sub-theme (B2)- ability to creatively transform failed value into positive value & bring it into the business model.**
  - Being able to encourage new ideas and supporting the implementation of new initiatives,
  - Being able to bring more value under your control by linking your knowledge to your benefit,
  - Being able to redesign the business model.

Chapter 8
Analysis of collaboration ability (Theme C) descriptive stage

This chapter presents the findings from the second stage of the research. The aim of the chapter is to explore in-depth and identify the sub-themes that comprise theme C (Collaboration). New data are used to elaborate on the theme, while adding new sub-themes and findings to the theme. The findings are compared against the existing literature to show it adds new detail and contributions to knowledge.

8.1 Collaboration (Theme C) - current understanding and existing knowledge:

The collaboration theme proposed by the author refers to evidence and observations found on the specific abilities that allow manufacturers to find solutions to improve their industrial sustainability by collaborating with partners across and outside the firm boundary.

Erin (2015) states there have been numerous calls for collaboration across sectors as the world faces increasingly large, complex social, economic and environmental problems. The authors for example (Senge et al., 2008; Kanter, 2009; Van Huijstee, 2010; Siegel, 2010; Gray et al., 2013; Evans et al., 2015) emphasise the importance of collaboration across organisations. Authors such as (Selsky, 2005; Gray et al., 2008; Gray et al., 2013; Erin, 2015) acknowledges the importance of multi-sector partnerships to draw on diverse abilities of partners from many sectors to tackle problems that individual organisations (or even whole sectors) cannot solve working independently. Gray et al. (2013) describe the importance of being able to *"combine resources, skills and knowledge from a wide range of stakeholders to address the challenges of creating a sustainable planet"*. Gray et al. (2013) state in the last decade the management literature has seen a dramatic increase in research on cross-sector

partnerships among businesses and NGOs. The importance of cross-disciplinary collaborations and partnerships within industry is escalating, driven by the need to address complex problems more systemically and from a multitude of perspectives (Hebel, 2007; Senge, 1990).

While this general trend towards increased collaboration has occurred, a rise in demand for improved industrial sustainability is observed. Industrial sustainability increases the need for collaboration further.

Reasons why collaboration is important for industrial sustainability:

Industrial symbiosis involves different independent industries exchanging by-products and residual resources, such as excess energy and water (Chertow et al., 2012). Industrial network to achieve industrial symbiosis requires high level of co-ordinations and collaboration between the actors in the eco-system (Duflou et al., 2012; Chertow and Ehrenfeld, 2012). Synergetic business relationships are suggested to aid organisation in making better use of by-products and waste energy.

Collaborations is suggested to be important to the development of effective systems of waste utilisation and circular economy, and also present opportunities for new synergistic industrial arrangements built around making use of others by-products and lost energy (Evans, 2015). Evans et al. (2015) in the report Industrial Evolution – Making British Manufacturing sustainable states greater collaboration between companies and other actors must be a central part of a more sustainable manufacturing system. The author describes although there are great potential benefits to working together across industries, supply chains, with universities and with other intermediary institutions, doing so requires forging deeper institutional connections and personal relationships which sit outside of businesses' core focus. Holmes and Smart (2009) describe the need for more research in 'sustainability-led' search partnership contexts.

Examples of organisations collaborating across boundaries for business model innovation are also receiving attention in literature and industry. It is increasingly suggested that business model innovation is a key to business success (Chesbrough,

2010, Schaltegger et al., 2012 and Zott et al., 2011). With the rising global sustainability pressures, collaboration between firms and other key stakeholders is becoming more important (Lowitt, 2013). The business model may be viewed as a new unit of analysis in business, which takes into account these collaborative ties (Zott et al., 201). Lifecycle impacts are often in other stages, and require collaboration with other parts of the system to reduce them (Chester, 2009).

The literature currently fails to provide evidence on abilities in reference to the ability to collaborate for industrial sustainability. Some authors for example (Selsky, 2005; Kanter, 2009) describe the importance of collaboration and describe one or two relationship types. Authors such as (Senge et al., 2008; Lozano, 2007; Zott et al., 2011; Gray, et al., 2013; Erin, 2015) acknowledge the importance of cross-sector partnerships for improving sustainability, but they do not seek to provide an ability-based view.

8.2 Findings of new sub-themes of the collaboration ability (C1, C2)

This section presents new or additional understanding on the ability of collaboration this includes emerging sub-themes that are described and evidenced.

Sub-theme C1 and C2

Most of the case companies described, the organisations ability to systematically innovate, capture failed value and create new forms of economic, environmental and social value, has been enhanced by being able to collaborate with actors across and outside the industry and sector. The interviewees specifically described the importance and need for developing more cross business and sector collaboration in their industry (i.e. collaborations with new and unfamiliar partners). Most companies described, the ability to look for new partners and collaborate with new organisations to be important. Companies also described how they have been able to find sustainability improvements by collaborating with unusual partners in unfamiliar areas. The author has grouped these findings and chosen the sub-themes C1 and C2.

- Sub-theme C1- ability to foster and nurture collaboration
- Sub-theme C2 - ability to look for new types of collaborators across and outside the firm boundary

Data on Sub-theme C1 -ability to foster and nurture collaboration and C2 -ability to look for new types of collaborators across and outside the firm boundary.

*"**External collaboration with non-traditional partners** is going to be ever more important in creating a sustainable future…Collaboration between businesses is not new…The sector is already working together on big environmental challenges through **multi-stakeholder roundtables and industry forums**….**in time some pretty interesting cross-sector collaborations will emerge…Selecting the right partner and partnership design will be key…**We find being able to **create a shared vision** that is similar or at least complementary being very **important for building relationships…building trust, co-creation and sharing is important** …potential to **combine resources**….multi-sector partnerships bring together **diverse expertise.**" (Company, C15, Interviewee 15A-CEO, transcript page 42).*

*"[Name of Company] wants customers to hand over an old or unwanted garment whenever they buy a new one…develop 'buy one-give one' culture which could **allow unwanted items to be resold, reused or recycled**… there are plenty of other opportunities out there businesses should be considering, the strategic assets **you have that others want, or those that others have that you want**…**….**An example is [Name of pilot program] collaboration with [Name of NGO]**.** [Name of NGO] **had the recycling asset and we** [Name of company] **had the clothes**…. the project is an example of doing business that is largely in the company's comfort zone and **with the usual suspects,** but perhaps **working in slightly different ways**, in this case rather than just buying and selling clothes, [Name of company] is also moving into the textile recycling sector... The recycled coat, we've just introduced retails at £89 – if we'd used virgin material it would cost £150… Such linear collaborations….are setting the foundations for what, in time, will become the blockbuster collaborations…**big collaborations between big businesses from very different sectors…**these might seem scary now, which is all the more reason to ensure you start developing the culture change now so you're ready to deal with them" (Company, C03, Interviewee 3A- Director of Sustainable Business, transcript page 12).*

*"[Name of collaborative project] has the potential to disrupt, the answers are out there, **we might not be talking to those inventors and solution providers out there** and this initiative get this out….an effort to **bring collective genius, unprecedented networks,** and new resources to overcome some of humanity's toughest sustainability challenges**…**How can we **move past incremental to real system shift**, how can we start thinking about the capabilities that are needed…..**new ways of collaboration**, moving from siloed investment to hybrid capital structures, **moving to new coalitions** and new ways of research and development **that is collective…**defining what is **pre-competitive** and what is competitive so that we can unlock a lot of the change that we need is important… a lot of the things we are going to be seeing in the future are **how companies collaborate differently**, the companies that are able to tap into the world as a global resource, companies that are able to develop this capability, organisations that are **able to collaborate differently are** going to succeed in the future. We are ushering into that new era of **systems innovation**, its no longer about open innovation or siloed innovation, its about how do we drive systems innovation…." (Company C19, Interviewee: 19D- Senior Director Systems Innovation, transcript page 54).*

*"**For every pair of jeans another laundry washes [Name of Company] washes 23.3 more jeans…[Company Name]** collaborated with some chemical scientist **to find out how to combine the chemical processes in its washes**… find low room temperature chemicals, We obtained knowledge from experts to get better**...Where another laundry takes 12 steps to reach a final wash, our organisation gets there in 6"** (Company C20, workshop participant, transcript page 56).*

*"Collaboration takes people from different worlds to places they might not have gone on their own…Of course, it **invites new ideas from the outside**, but it also **accelerates your own thinking**…In my experience**, when the right creatives connect**, it can be like setting off a chemical reaction...We are fortunate at [Name of Company] because we have the **opportunity to work with a lot of different communities**…**linking with the right partner**…ability to **successfully predict and partner with people** of equivalent stature as well as those on the cusp of redefining their respective industries has been important...**Mutual learning is absolutely critical to any successful partnership**.*

*We bring an expert to the table – whether it's athlete insights or material innovation or global reach – that **many of our creative partners don't have**…**we then look to our partners to provide an insight or skill or point of view that we may not have**. By **combining knowledge**, we **bring out the best in each other**...But it goes deeper than just an exchange of knowledge. There's a more personal benefit to [Name of Company] that's harder to measure. Being **open and curious to the world through collaboration** is a way to nourish and inspire our own creative culture… You really have to be **passionate about the same parts of the universe for any partnership to work**…When you look back at the last 10 years, **these partnerships have really accelerated across our business.**..We worked with [Name of Information Technology Company] to develop [Name of IT Product], a platform that forever changed how we look at servicing the athlete and motivating people to do more…From a manufacturing perspective, **collaborations can be the quickest way to disrupt existing models**. With [Name of Shoe] for example, we worked with others for six years to reconfigure **apparel machines to make footwear** uppers. It's opened up a world of **new design possibilities**…. In a similar way, we've invested in a company that has invented a way to dye products without water….. If you consider it takes 30 liters of water to dye a single T-shirt, the impact could be massive... A recent example is when we shared eight years of materials research and analysis with the students at the [Name of University] to improve an app that we were developing. The result is the [Name of App] that allows any designer to know the sustainable impact of the materials they choose. It's been downloaded in 132 countries…**Collaboration is a powerful strategy for unlocking new opportunities**…I firmly believe that our future potential will be based, in large part, **on our ability to collaborate with the right partners in the right ways…**It's clear to me that if all the ingredients are right, **collaboration can help shape your vision of the future and get you there faster**" (Company C19, Interviewee 19A- Director Sustainable Business & Innovation, transcript page 53).*

*"We have been able to find solutions to a lot of the complex issues….. **by finding partners** with the **new capability and knowledge we did not have**…these partnerships also brought **new thinking and ways of doing business outside the norm**…..We have found solutions by **piloting projects and leveraging the knowledge from each other...**we have been able to **find the partners sometimes by surprise** for example by finding those tackling similar challenges**…Sometimes we have found partners accidently**...for example by networking and speaking about our ambitions with a larger community….Its important to be able to **communicate ideas with the wider community...**(Name of Project) enabled us to experiment with our off-cut waste, the partnership enabled us to create value from this….learning together by starting pilots…**building networks and relationship** this has enabled us to be able to find new partners" (Company C26, workshop participant, transcript page 76).*

*"Collaboration with suppliers has been a hallmark of many of the improvements…from working with farmers to improve yield, optimise fertilizer use and extend the producing season…. collaborating with [Name of Engine Manufacturer] to optimise the operation of CHP gas turbine… **careful consideration of when to partner, when to bring expertise in**, and when to outsource new co-product operations has also underpinned the development of new lines of business…." (Company C02, Interviewee 2B- Head of Engineering, transcript page 9).*

*"**Finding different ways of enganging and collaborating with new organisations has become key**…we started looking at how we could make our business more socially as well as environmentally responsible **collectively**… We wouldn't have been **looking at** the **fishing industry as a source for materials**, if we hadn't started on that path…The [name of project] involves buying thousands of miles of old fishing nets from remote communities in the Philippines and turning them into carpet tiles... [Name of project] provides a source of income for small fishing community…while cleaning up their beaches and waters of discarded fishing nets that threaten their livelihood and the very precious double barrier reef off their shore…discarded fishing nets are collected and sold to our trusted yarn supplier and partner…re-purposing waste nylon from discarded fishing nets and other sources…is not just about beach cleanup, though that is a vital piece. It is also helping the villagers establish new financial opportunities by providing an additional income stream …**Collaboration between different types of actors can yield in previously unimagined solutions"** (Company, C10, Interviewee* 10A- Sustainability Director, *transcript page 32).*

All interviewees described collaboration for improving industrial sustainability is important; no one organisation stated they can do it on their own. Even Company C02 for example collaborates with their farmers to improve sustainability performance and this organisation is one of the most independent firms, that has a reputation for creating value and by-products by bring everything under its control. Most companies for example (C15, C03, C20, C19, C02, C26, C10) described that, no single organisation has the knowledge or resources to do it alone. "*The issues we face are so big and the targets are so challenging that we cannot do it alone. When you look at any issue, such as food or water scarcity, it is very clear that no individual institution, government or company can provide the solution*" (Gray, et al., 2013). The literature on collaboration being important for example (Senge et al., 2008; Selsky, 2005; Erin, 2015) is well understood, the data agrees with this literature. Doing collaboration is not new, but how to do cross-business system collaboration is. The data suggests the importance of some interesting cross-sector and business collaborations; system transformation to sustainable industrial systems and sustainable business models requires more cross-business system collaboration that is not yet fully realised (Evans, 2015). This section describes the new and interesting insights that emerge from the

data on the sub-themes C1 and C2;

Sub-theme C1- ability to foster and nurture collaboration.

Sub-theme C2 - ability to look for new types of collaborators across and outside the firm boundary.

8.2.1 Discussion sub-theme C1 (ability to foster and nurture collaboration)

In this section in particular the data refers to actions. In the data many of these sub-abilities were referred to by interviewees not as abilities but as solutions (i.e. we did this). They referred to how they did something, not what they needed to be good at, it was only through the interview and analysis process the researcher transformed the findings from an action into an ability (i.e. what ability do you need to be able to do that action).

Most companies described sub-abilities such has being able to create a **shared vision**, and being able to creating mutual benefit (I.e. win-win for both parties engaging**)** being important factors to make a relationship work. Company C15 for example described "*selecting the right partner and partnership design will be key…We find being able to create a shared vision that is similar or at least complementary being very important for building relationships**".*** Company C19 described, "***Mutual learning*** *is absolutely critical to any successful partnership".* **Trust between the partners** was described to be important as well. Company C26 for example described *"each part of the system **trusting the other parts** to operate as promised*" being important. Company C19 also described passion being important, "*You really have to be **passionate** about the same parts of the universe for any partnership to work**".***
Interestingly the data also suggests that **being able to create pre-competitive space** provided by industry affiliations fosters and enables collaboration between different actors across the industry. Company C25 that is the sustainable apparel and footwear Industry coalition is observed to be able to bring together actors from across the sector and aid organisations to collaborate in a **pre-competitive** space. The pre-competitive space the industry affiliations creates, is suggested by industry players to **fosters best practice and knowledge sharing** and enable different actors to engage in the system

to solve complex sustainability issues. Company C25 described "*it **catalyses conversations between individuals who usually share a similar vision**, **in spite of working for competing organisations**…By joining forces in a Coalition, we can address the urgent, systemic challenges that are impossible to change alone…By joining working groups where different organisations can share their expertise with the industry as a whole as well as one-on-one with their peers …the working groups provides a platform for different players with different expertise to engage in finding solutions…members become leaders in their fields and influential voices in the development"*. The data suggests industry coalitions might be in a **unique position to connect different groups** in a way, which might not otherwise have occurred. Company C25 describes, "*mutually beneficial relationships can form around the exchange of ideas, or the linking of the right groups and individuals"*.

Interestingly some organisations for example C26 described collaboration challenges, such as being able to **develop common vocabularies** and making sense of difficult concepts together being challenging. Most organisations described being able to create greater cross-sector collaboration and sharing of knowledge being important but challenging to do due to cultural and leadership barriers.

8.2.2 Discussion sub-theme C2 (ability to look for new types of collaborators across and outside the firm boundary)

Most companies for example (C15, C03, C20, C19, C02, C26, C10) described the **ability to look for new types of collaborators across the firm boundary** being important to improve industrial sustainability. Company C15 for example described "*external **collaboration with non-traditional partners** is going to be an ever more important in creating a sustainable future". Company C19 described, "A lot of the things we are going to be seeing in the future are **how companies collaborate differently**"*. The ability to find new partners (i.e. **which might be very different from existing partners**) and form new types of collaboration between different actors appears to be important across the data. Company C20 a jeans manufacturer collaborated with a chemical company to find solutions to reduce the water used in its processes. Company C03 a clothing retailer collaborated with an NGO to find solutions for the end of life garments going to landfill. Company C10 a carpet

manufacturer collaborated with remote fishing communities and yarn suppliers to collect discarded fishing nets and repurpose the waste to create new products and clean up the beaches. Interestingly the data suggests that, the ability to develop new relationships with **unusual partners** (i.e. non traditional partners) or change the nature of existing relationships can generate new spaces for innovations and opportunities to improve industrial sustainability. Company C26 for example described "*We have been able to find solutions to a lot of the complex issues…by* ***finding partners with the new capability and knowledge*** *we did not have…these partnerships also brought new thinking and ways of doing business outside the norm…We have found solutions by piloting projects and leveraging the knowledge from each other". Company C03 described, "there are plenty of other opportunities out there businesses should be considering, the strategic assets* ***you have that others want, or those that others have that you want****...An example is [Name of pilot program] collaboration with [Name of NGO]****.*** *[Name of NGO]* ***had the recycling asset and we*** *[Name of company]* ***had the clothes****…. the project is an example of doing business that is largely in the company's comfort zone and* ***with the usual suspects,*** *but perhaps* ***working in slightly different ways****, in this case rather than just buying and selling clothes, [Name of company] is also moving into the textile recycling sector".* The data suggests that working with the unusual partners can enable radical ideas, Company C20 for example "*for every pair of jeans another laundry washes [Name of Company] washes 23.3 more jeans"*; unusual partners can increase the potential for innovation by bringing new capability, knowledge and thinking. The **organisation developing this ability to find new partners**, are observed to benefit from utilisation of knowledge and expertise attained from **interactions with non-traditional companies** (i.e. collaborations with new and unfamiliar partners). Interestingly the data suggests sustainability innovation, particularly radical innovation happens when connecting previously unconnected bodies of knowledge, continuing to collaborate with the same people from the same context in the same way may not achieve that (e.g. Company C15, C03, C20, C19, C02, C26, C10).

Developing the **ability to look for new types of collaborators across the firm boundary appears to be important across the data.** Company C20 for example

described being able to **actively search for actors with different capability and knowledge** being important. Company C19 is observed to use **a more structured approach to bring industry players together** to search solutions to solve a particular problem. Company C19 described a program it has launched to bring different actors in a system together in an effort *"to bring collective genius, unprecedented networks, and new resources to overcome some of humanity's toughest sustainability challenges"*. Interestingly most organisations interviewed, described they have been able to find partners by networking (e.g. through industry affiliations), speaking to others tackling similar issues, and by being able to visit and engage with many actors. For example company *C26 described "we have been able to **find the partners sometimes by surprise** for example by finding those tackling similar challenges**…Sometimes we have found partners accidently**..for example by networking and speaking about our ambitions with a larger community in the system*". Interviewee C18 described, *"Finding these partners requires the active pursuit of serendipity"*. Interestingly the data suggests that organisations developing the ability and **willingness to look outside of their core business and collaborate with others in an unfamiliar** area appear to be able to find interesting solutions (Company C15, C03, C20, C19, C02, C26, C10). For example Company C03 a retailer collaborating with charity partner (NGO) on recycling clothing.

The authors (Erin, 2015; Edmondson, 2012; Holmes and Smart 2009; Senge et al., 2008) have come closest in their comments to describing the importance of collaboration across organisations. Senge et al. (2008) states aaccelerating change in critical systems that shape our future requires networks of collaboration and knowledge. The authors (Edmondson, 2012; Senge et al., 2008) highlight the benefit of the potential to combine resources, skills and knowledge from a wide range of stakeholders to address the challenges of creating a sustainable planet. Authors such as (Edmondson, 2012; Senge et al., 2008) describe to address problems that are too complex for a single organisation to address, a growing number of projects involve collaboration among partners from different firms and industries. Eggers and Macmillan (2013) describe the importance of leveraging the resources and knowledge of a diversity of stakeholders including governments, private firms, education institutions and NGOs to address sustainability challenges. Beattie and Smith (2013)

describe and provide understanding on how value is no longer created by firms acting autonomously, but by firms acting together with parties external to the firm through informal arrangements or formal alliances. Auvergne and Lister (2013) highlight an increasing number of large corporations initiating collaborative sustainability governance within networks. This involves engaging proactively with a broader range of stakeholders, often including non-industry actors (e.g. WWF partnering with Coca-Cola) and competitors to establish industry-level sustainability consortia (e.g. The Sustainable Apparel Coalition).

However, none of the above researchers present an ability-based view understanding towards the collaboration ability. The data from across the cases (example C15, C03, C20, C19, C02, C26, C10) suggests some abilities that aid improve and develop Sub-theme C1 ability to foster and nurture collaboration; being able to develop a shared vision, being able to create mutual learning, being able to develop trust between the partners, being able to create pre-competitive space, being able to foster best practice and knowledge sharing is suggested to be important. Interestingly the data suggests the ability to look for new types of collaborators across and outside the firm boundary being important (sub-theme C2). Being able to look outside core business and collaborate with others in an unfamiliar area and interacting with non-traditional companies (i.e. collaborations with new and unfamiliar partners) is suggested to be important. The sub-theme C1 and C2 is therefore a confirmed theme of the collaboration ability (Theme C).

Bringing the data together the author proposes to define the ability C as **'ability to look for new types of collaborators up and down and outside the current value chain'**

8.3 Summary of findings from the collaboration ability

Bringing the findings together the author defines the collaboration ability as;

Collaboration theme (C)- ability to look for new types of collaborators up and down and outside the current value chain.

- **Sub-theme (C1) – ability to foster and nurture collaboration**.
  - Being able to develop a shared vision,
  - Being able to create mutual learning,
  - Being able to develop trust between the partners,
  - Being able to create pre-competitive space,
  - Being able to foster best practice and knowledge sharing.

- **Sub-theme (C2) – ability to look for new types of collaborators across the firm boundary.**
  - Being able to look outside core business and collaborate with others in an unfamiliar area,
  - Being able to actively search for new actors with different capability and knowledge,
  - Being able to Interact with non-traditional companies.

Chapter 9
Analysis of whole system design ability (Theme D) descriptive stage

This chapter presents the findings from the second stage of the research. The aim of the chapter is to explore in-depth and identify the sub-themes that comprise theme D (whole system design ability). New data are used to elaborate on the theme, while adding new sub-themes and findings to the theme. The findings are compared against the existing literature to show it adds new detail and contributions to knowledge.

9.1 Whole system design ability (Theme D) - current understanding and existing knowledge:

The whole system design ability proposed by the author refers to evidence and observations found on the abilities that allow manufacturers to find solutions to improve industrial sustainability by being able to make the system bigger and find interactions (win-win's) in a system to focus and prioritise efforts.

Senge (2008) states the un-healthiness of the world today is due to our **inability to see it as a whole**. Anarow et al. (2003) articulated the idea that sustainability could be achieved only if society moves towards a whole system thinking; addressing the problem at a system level. Anarow et al. (2003) states whole systems thinkers *"see wholes instead of parts, interrelationships and patterns, rather than individual things and static snapshots".* The literature on whole system design approaches encourages those seeking a solution to a particular industrial problem to regard a problem as a whole system and not just to concentrate on one particular element of that system (Anarow et al., 2003). Anarow et al. (2003) states the approach focuses on

interactions between the elements of a system as a way to understand and change the system itself. For example the literature on whole-systems thinking pays close attention to **incentives and feedback loops** within a system as ways to **change how a system behaves** (Senge, 2008). Senge (2008) states that without whole systems perspective crucial impacts between elements could be missed, therefore disrupting the system as a whole. Anarow et al. (2003) state that *"sustainability cannot be achieved in the absence of whole-systems thinking",* an ability that appears to be essential to improve industrial sustainability.

There are currently multiple terms being used to describe holistic and integrated approaches to the design of more radically innovative and sustainable solutions (Coley and Lemon, 2009). Authors suggest that understanding the dynamics of a system is integral to the whole system approach (Rocky Mountain Institute, 2004; Gunderson and Holling, 2002). The Rocky Mountain Institute (2009) highlights systems thinking as the method that should be utilised not only to point the way to solutions to particular resource problems, but also to reveal **interconnections** between problems, which often permits one solution to **be leveraged to create many more.** Rocky Mountain Institute (2009) states *"Whole system design means optimising not just parts but the entire system ... it takes ingenuity, intuition, and teamwork. Everything must be considered simultaneously and analysed to reveal mutually advantageous interactions (synergies) as well as undesirable ones"*. The greatest opportunity to reduce the environmental impact of an industrial system comes about when we consider the system as a whole, because the optimisation of any one part is ultimately constrained by other aspects (Evans et al., 2009). Evans et al. (2009) describes sub-system approaches that can dramatically improve sustainability; but to help future generations meet the needs of humanity within the carrying capacity of the planet it will be important to develop the know-how to enable changes across the whole industrial system.

Concepts such as circularity (Ehrenfield, 2008; Braungart et al., 2007), systems thinking (Capra, 1996; Forrester, 2007; Senge, 1990, 2008; Cabrera, et al., 2015) and whole system design (Hawken et al. 1999; Anarow et al., 2003; Charnley et al., 2011) provide compelling principles on which future sustainable industrial systems might be

built. However there is a lack of practical understanding of what abilities are required for organisations to be able to implement these visions and concepts. Pioneering authors in the systems transformation literature for example (Anarow et al., 2003; Senge, 2006, 2008; Rocky Mountain Institute, 2004; Meadows, 2008; Charnley et al., 2011) describe the importance of understanding the interactions between the elements of a system and taking a whole system view; this research and data agrees with this literature. Meadows (2008) describes the importance of leverage points to intervene in a system and proactively change a given system's overall behaviour or even transform it entirely, and Senge (2008) provides understanding of the importance of systems thinking in building a learning organisation; but does not seek to provide a ability-based view. Senge's (2008) observations and research comes the closest to this research in providing understanding of systems thinking being an essential ability for a learning organisation to move towards a sustainable industrial system.

9.2 Findings of new sub-themes of the whole system design (D1, D2):

This section presents new or additional understanding on the ability of whole system design, this includes emerging sub-themes that are described and evidenced.

Sub-theme D1 and D2

Some companies specifically described and demonstrated examples of how they have been able to find system level sustainable solutions by 'taking a systems view', 'redefining the business purpose taking a long-term view towards value generation', 'collaborating with new players across the business system', and 'finding best points of leverage'. Interestingly the data suggests that, identifying best points of intervention (i.e. win-win interaction, positive feedback loop), and the ability to make the system boundary bigger as being important. The author has grouped these findings and chosen the sub-themes D1 and D2.

- Sub-theme D1- ability to make the system bigger to uncover new solution opportunities.
- Sub-theme D2 - ability to look for key interdependencies where greater impact can be achieved.

Data on Sub-theme D1- ability to make the system bigger to uncover new solution opportunities and D2 - ability to look for key interdependencies where greater impact can be achieved.

"from the original coffee plant we use less than 5% to make our cup of coffee while we discard all the rest ...Learning how to use ***systems thinking can be immensely inspiring and constructive****...The "Pulp to Protein" program was aimed at fighting malnutrition and created thousands of jobs in Colombia…****this innovation*** *was aimed at pulling the poor out of the threshold of disappearing…..'Pulp to Protein' program provides employment, nutritious diet and most of all the security of sustenance to those who need it most around the world….A coffee bean is made of only 5% of the coffee 'cherry'. The left over is the coffee pulp,* ***usually considered a waste****….****which can be used as a substrate for growing mushrooms****. [company name****] helped coffee farms to utilise their coffee pulp by growing mushrooms on them****…. as coffee is rich in caffeine it was found that* ***mushrooms 'rich in protein' grew three times faster in 'coffee waste' than normally.*** *It was also 80% more energy efficient as it saved the process of making substrates for mushroom cultivation. Further, any waste left could be used as animal feed due to its richness in amino acids (especially lysine) or used as compost for other plant or vegetable crops. Also, the mushroom spores convert the mulch into a fibre-rich feed, which can be used as animal feed (goats and other livestock). The animal dung can again be composted for nurturing supplementary food crops.…*the business model converts all waste into a **value added cascade…***This* ***loop signifies a complete 'zero waste'*** *solution….****multiple benefits*** *from* ***one intervention in the system****…due to trading of mushrooms, farmers can now also buy livestock, children's school fees can be paid along with buying household items…"(Company C16, Interviewee, 16A- Initiator of The Blue Economy, transcript page 44).*

*"****Most designers are busy optimising sub-systems****, while no designer is responsible for the whole…. Many excellent writings and teachings emphasise* ***'system-level change' or whole system design****. This concept contradicts many of our professional instincts. Instead of starting with a tough problem and reducing it to sub-problems allocated to subject experts, resulting in solutions we expect: more technology and incremental performance improvements****…***we need to ***embrace the whole problem and look for useful interactions between the components"*** *(Interviewee 18A - Director Centre for Industrial Sustainability, transcript page 52).*

Systems thinkers one of their particular skills is ***spotting key levers of change****, which individual actors within a particular system might well miss… A particularly useful tool is developing a* ***dynamic visual map*** *of the system you are seeking to influence… What these complex maps are able to do is* ***help individual characters understand the system they are operating in****...They are also critical in* ***generating different types of conversation****. There is something powerful about the physicality of standing around a map having a debate that is very different from sitting round a table talking…* ***As you go deep, you find interconnections you did not even know exist****…. If you look at the whole system, you realise the barriers are in our minds. What moves that forward is a willingness to change behaviours and come together to* ***collaborate on identified solution****s that has multiple benefits to the business, planet and society" (Company C26, workshop participant, transcript page 77).*

*"We are working on a **systems change programme** to eliminate hazardous chemicals from supply chains and products…**System maps** are a tool for dialogue and once that happens around a **common perspective**, it becomes a lot easier. Without a map, it just becomes arguments in pieces rather than the **system as a whole**… Creating a map has **stimulated a lot of dialogue** and **helped create a shared vision** so everyone can come together and take **action in their own parts of the system**" (Company C14, Interviewee 14A-Committee head, transcript page 39).*

*"[Company Name] is **actively engaged in system innovation**…we contract to around 900 factories directly and use a palette of more than 16,000 materials… the volatility caused by resource scarcity and customer demands for transparency has the potential to disrupt our business…response **requires action that actually transforms the systems** in which the company operates…Materials is one of the focus..About 60% of the environmental footprint of a pair of shoes is in the materials…[Company Name] practical approach to **shifting this system** started with our own innovation, and developed the open-source [Name of sustainable materials database] to help designers select better materials… we opened this to the whole industry, so we can share it as a tool to keep the index updated…data is nothing if its not in the hands of those who make the decisions, so how do you get this complex technical data, out of the dark box of the scientist and the geeky people into the finger tips of designers and makers and procurement officers who are the ones that choose the materials**. **If you give people the power to choose better materials that creates huge market pull in terms of system change that we are trying to achieve**…..But making information available is just the start – **to get the level of innovation needed requires wider change in the system**. [Company name] is using [Name of Collective Change program] to accelerate a revolution in sustainable materials. This approach started **by getting the materials system 'in the room' to diagnose challenges and innovate** – from green chemistry and closed-loop manufacturing to new finance and consumer engagement. The use **of sophisticated game and system mapping** helped chemical companies, brands, non-governmental organisations (NGOs) and thinkers really **understand the challenge and find new solutions**. These ideas, and others identified through the network, will be fed into the [Name of Collective Change program] acceleration process so that the best ones can be developed and brought to scale…..a starting point for **experimentation and learning**… If we are to get to a sustainable future we need to be more sophisticated and joined up in the way we act. We need to **get better at diagnosing systems and identifying the optimal places for focus**. We need to ensure that **actions are multifaceted** – that **a range of things come together at the same time**. And we also need a way to **address the barriers to change as a collective, rather than as separate individuals or organisations.**" (Company C19, Interviewee 19A- Director Sustainable Business & Innovation, transcript page 53).*

*"…**We stepped back and looked at the whole system**…**We came up with many innovative solutions** from products where no pattern matching was required, minimal glue, closed loop systems-take-back model…services redesign...extract more revenue per square meter of carpet sold, by adding in new services…we started evolving into a highly innovative company….**the systems approach helped us come up with better ways of improving the status quo**…The [name of project] involves buying thousands of miles of old fishing nets from remote communities in the Philippines and turning them into carpet tiles... [Name of project] provides a source of income for small fishing community…while cleaning up their beaches and waters of discarded fishing nets that threaten their livelihood and the very precious double barrier reef off their shore…discarded fishing nets are collected and sold to our trusted yarn supplier and partner…re-purposing waste nylon from discarded fishing nets and other sources…is not just about beach cleanup, though that is a vital piece. It is also helping the villagers establish new financial opportunities by providing an additional income stream.**"** (Company, C10, Interviewee* 10A- Sustainability Director, *transcript page 32).*

9.2.1 Discussion sub-theme D1 (ability to make the system bigger to uncover new solution opportunities)

Some of the companies (For example C19, C26, C18, C16, C10, C17) described how they have been able to find solutions to complex problems by being able to look outside the core business and develop the ability to be able to make the system boundary they operate in bigger to uncover new solution opportunities.

Company C10 a carpet manufacturer collaborated with remote fishing communities (i.e. finding connections outside its traditional system boundary) and yarn suppliers to collect discarded fishing nets and repurpose the waste to create new products and clean up the beaches. This example illustrates how company C10 by being able to make the system it operates in bigger, has been able to seek and **find alternate materials** such as finishing nets as a source of raw material to manufacture carpet instead of virgin materials used traditionally. The finishing net is described to otherwise be discarded as waste and pollute the oceans. Company C10 described, *"...**We stepped back and looked at the whole system**...**we came up with many innovative solutions** ....the **systems approach helped us** come up with better ways of improving the status quo….*". Company C16 describes making the system bigger (i.e. looking outside the business model of just selling coffee) and being able to find opportunities to help improve the coffee farmer's livelihood and their living conditions by identifying ways of generating additional revenue from growing mushrooms farmed on coffee waste. Company C16 described, "*Learning how to use systems thinking can be immensely inspiring and constructive…This **loop signifies a complete 'zero waste'** solution…. **multiple benefits** from **one intervention in the system**…due to trading of mushrooms, farmers can now also buy livestock, children's school fees can be paid along with buying household items"*. From Company C16 and C10 the data suggests that by developing this ability to make the system bigger, the companies have been able to find solutions to **create positive value for a range of stakeholders** including the society and planet (i.e. have a positive impacts and multiple benefits; on environmental, energy and resource issues, and contribute towards delivering the broader long-term well-being of society). The data also suggests that companies developing this ability to make the system bigger are able to

think beyond business as usual and are able to change their business model and collaborate and work with others in unfamiliar areas (E.g. Company C10, C16, C19, C14).

Over 60% of the companies interestingly suggested systems mapping technique as a good technique to learn to develop the ability to make the system bigger. The companies described **system mapping** (for example actor mapping, causal-loop) being a good technique to aid organisation to look for solutions outside their current business and find new connections and partners. Company C14 described *"Creating a map has **stimulated a lot of dialogue** and **helped create a shared vision** so everyone can come together and take **action in their own parts of the system**." Company C26 described "What these complex maps are able to do is **help individual characters understand the system they are operating in**..They are also critical in **generating different types of conversation**. There is something powerful about the physicality of standing around a map having a debate that is very different from sitting round a table talking… As you go deep, you find interconnections you did not even know exist"*. The data suggests that the actor and relationship mapping technique aids individuals to understand complex systems, by providing a shared understanding of the system they operate in, and the mapping is also described to aid create dialogue with multiple stakeholders that is described to facilitate organisations to **uncover sustainability improvement opportunities for value capture across the system** (e.g. Company C19, C14, C16). Company C14 described using the mapping technique to bring together multiple stakeholder to communication, design and implement a zero discharge of hazardous chemicals in the global textile and footwear industries, it has been able to and make system level change and improve the environment and people's well being. The data suggests that the systems mapping (normally of **actors and relationships**) helps develop this ability to make the system bigger, and sub-abilities such as **co-creation of a shared vision** of the future is described to be important in the process. The data also suggests that the use of techniques like system maps aid organisation to form a shared understanding of the system with multiple stakeholders (e.g. Company C14).

9.2.2 Discussion sub-theme D2 (ability to look for key interdependencies where greater impact can be achieved)

The data suggests that some of the organisations that have developed the above sub-theme D1 the ability to make the system bigger, are then found to be developing the ability to find places in the system to focus efforts where the greater impact can be achieved (Sub-theme D2); most organisations (e.g. Company C10, C14, C16, C19, C17) described this as the ability to find points of best leverage; these are described by the organisations as places in the system where concentrated actions could create multiple results (often with positive feedback loop). Company C19 described "*We believe in putting our energy* ***where we have the most impact.*** *Our footprinting work has confirmed that the finished goods manufacturing part of our value chain is where many of our biggest impacts on people and the environment are felt. Our* ***systems mapping has helped us understand the interrelationships and identify our points of leverage in the complex manufacturing supply chain.****"* Interviewee 18A described *"Most designers are busy optimizing sub-systems, while no designer is responsible for the whole…. Many excellent writings and teachings emphasise system-level change or whole system design. This concept contradicts many of our professional instincts. Instead of starting with a tough problem and reducing it to sub-problems allocated to subject experts, resulting in solutions we expect: more technology and incremental performance improvements…we need to embrace the whole problem and* ***look for useful interactions between the components****."*

It is observed in the research, mapping the actors in the system and their relationship is a useful exercise for creating a common understanding of what's in, and out of the system. This process is also observed to facilitate the **identification of key interdependence** (e.g. workshop with Company C26, C20, C22). Company C04 is a SME automobile company that aims to produce mobility at zero cost to the planet. The company describes a business model, where the company sells mobility to driver and they (i.e. the company) pay for the fuel. It is win-win and a positive feedback loop because, it incentives company C04 to put in technology that customer would otherwise not pay for if they were buying the car. The case company offers an example of **how it has found advantageous connections across the system** and

demonstrates maturity in the whole systems design ability (i.e. design of a vehicle system providing mobility as a service). The company describes, "*If you are motivated to sell new cars, you become less inclined, for example, to use the most durable materials. The [name of Company] have coined the phrase '**selling mobility as a service**' cars are offered as part of a service contract. At a result, designing cars of **excellent and lasting quality becomes good business sense**; whilst the unsustainable practice of 'designing for obsolescence' deliberately designing cars that the customer will soon wish to replace becomes a thing of the past".* The company offers an example of how it has **found advantageous connections across the system** and illustrates maturity in the whole systems design ability. The car company, by taking a systems view, internalised the fuel cost, the company pays for the fuel and customer the distance travelled. The car company by taking a systems view has been able to identify a key **interdependencies that drive system performance**. The company is **able to look for win-win interactions in a system,** and has identified and focused its efforts on making the car light. Company C04 describes*"...this then resulted in a lighter engine needed because it is a smaller car, then the brakes needed to be less powerful, because the car was less heavy, then the requirement was you can put less fuel in it. The petrol tank gets smaller and lighter. If everything gets lighter, you can make the engine light because it needs to move less metal*" this is an example of a win-win interaction and positive feedback. In C04 it is clear that extensive management effort has been focused on taking a systems view and identifying the best leverage point in the planning process of developing the companies business model of producing mobility at zero cost to the planet. *Company C19 a* multinational footwear company*, "If we are to get to a sustainable future we need to be more sophisticated and joined up in the way we act. We need to **get better at diagnosing systems and identifying the optimal places for focus**. We need to ensure that **actions are multifaceted** – that **a range of things comes together at the same time**. And we also need a way to **address the barriers to change as a collective, rather than as separate individuals or organisations**".* The data also suggest that, system-level innovation may not happen in the current value chain of an organisation, because organisations already explore all the different variables and have access to it already (i.e. the company already knows it's suppliers and the value chain). It is observed that organisations that have been able to look for new variables/connections

outside the firm boundary have been able to find better solutions to improve industrial sustainability. The data suggests that, in most cases, the variable is owned by an actor who is outside the industry i.e. who is an unusual partner. Companies developing this ability appear to be taking a longer term and system-wide perspective on value rather than short-term gain. The data suggests that there is a need for more cross-business system collaboration.

The authors (Senge, 2008; Anarow et al., 2003; Charnley et al., 2011, Cabrera et al., 2015) have come closest in their comments to describing the importance a systems thinking approach, in identifying and understanding connections, exchanges, and interactions between stakeholders. The data agrees with this literature and suggests that organisations developing this ability (D1 and D2); are able to identify interesting connections, key points of leverage in the system, and ultimately uncover opportunities to do things differently to improve industrial sustainability. (Senge, 2008) presents systems thinking as an important ability for dealing with complexity is systems. The research provides understanding of how the approach aids the ability to

- See how organisational systems (e.g., internal/external conditions, processes, people) interact and influence each other,
- How these systems create and contribute to specific issues and strengths.

According to Peter Senge (2006), the three characteristics of systems thinking include:

- A consistent and strong commitment to learning
- A willingness to challenge your own mental model – accepting your own role in problems and being open to different ways of seeing and doing
- Always including multiple perspectives when looking at a phenomenon

However, this does not present an ability-based view understanding towards the whole system design. The data from across the cases (example C04, C16, C19, C14, C26) brings new interesting insights and understanding on how some organisations are developing and practicing this ability; some sub-abilities such as being able to set and broaden the system boundary, being able to use actor and relationship mapping, being able to skillfully co-create a shared vision of the future, being able to look outside current business, being able to look for key interdependencies that drive

system performance, being able to find points of best leverage, being able to prioritise effort/intervention, and being able to find new connections outside the firm boundary appear to be important.

The sub-theme D1 (ability to make the system bigger to uncover new solution opportunities) and the sub-theme D2 (ability to look for key interdependencies where greater impact can be achieved) is therefore a confirmed theme of the whole system design ability (Theme D).

Bringing the data together the author proposes to define the ability D as **'ability to find advantageous connections across the system'**

9.3 Summary of findings from the whole system design ability

Bringing the findings together the author defines the whole system design ability as;

Whole system design theme (D)- ability to find advantageous connections across the system.

- **Sub-theme (D1) – ability to make the system bigger to uncover new solution opportunities.**
  - Being able to set and broaden the system boundary,
  - Being able to use actor and relationship mapping,
  - Being able to skillfully co-create a shared vision of the future,
  - Being able to look outside current business and finding new partners & connections.

- **Sub-theme (D2) – ability to look for key interdependencies where greater impact can be achieved.**
  - Being able to find points of best leverage (e.g. win-win, positive feedback),
  - Being able to prioritise effort/intervention,
  - Being able to find new connections outside the firm boundary.

9.4 Summary of findings chapter 6,7,8,9.

Efficiency theme (A)- ability to see environmental and social waste and creatively and systematically reduce them.

- **Sub-theme (A1)- ability to see environmental and social waste**
  - Being able to see waste,
  - Being able to be physically present at the location.
- **Sub-theme (A2)- ability to find creative solutions for environmental and social waste.**
  - Being able to experiment,
  - Being able to learn by doing.
- **Sub-theme (A3)- ability to identify improvements in a systematic way and make it routine.**
  - Being able to develop routines,
  - Being able to share best practices across sites,
  - Being able to standardise practices,
  - Being able to develop shared long term-vision,
  - Being able to set challenging environmental and social targets,
  - Being able to find the fundamental minimum,
  - Being able to solve problems using lateral thinking,
  - Being able to develop the ability to identify root causes.

Internalisation theme (B)- ability to see failed value exchanges and deliberately bring them into the business model.

- **Sub-theme (B1) - ability to see failed value exchanges**
  - Being able to see and discover failed value exchanges across the current system and the firms network of stakeholders,
  - Being able to discover failed value types in the network,
    - Type A (I give, but don't get a return)
    - Type B (I give, but you don't want)
    - Type C (I don't give but you want)
    - Type D (I have too much)
- **Sub-theme (B2)- ability to creatively transform failed value into positive value & bring it into the business model.**
  - Being able to encourage new ideas and supporting the implementation of new initiatives,
  - Being able to bring more value under your control by linking your knowledge to your benefit,
  - Being able to redesign the business model.

Collaboration theme (C)- ability to look for new types of collaborators up and down and outside the current value chain.

- **Sub-theme (C1) – ability to foster and nurture collaboration.**
  - Being able to develop a shared vision,
  - Being able to create mutual learning,
  - Being able to develop trust between the partners,
  - Being able to create pre-competitive space,
  - Being able to foster best practice and knowledge sharing.
- **Sub-theme (C2) – ability to look for new types of collaborators across the firm boundary.**
  - Being able to look outside core business and collaborate with others in an unfamiliar area,
  - Being able to actively search for new actors with different capability and knowledge,
  - Being able to Interact with non-traditional companies.

Whole system design theme (D)- ability to find advantageous connections across the system.

- **Sub-theme (D1) – ability to make the system bigger to uncover new solution opportunities.**
  - Being able to set and broaden the system boundary,
  - Being able to use actor and relationship mapping,
  - Being able to skillfully co-create a shared vision of the future,
  - Being able to look outside current business and finding new partners & connections.
- **Sub-theme (D2) – ability to look for key interdependencies where greater impact can be achieved.**
  - Being able to find points of best leverage (e.g. win-win, positive feedback),
  - Being able to prioritise effort/intervention,
  - Being able to find new connections outside the firm boundary.

Chapter 10
Synthesis and framework

This chapter presents the bigger patterns in the analysis and the conceptual framework

10.1 Bigger patterns in the data (synthesis)

This section presents the researchers perspective and bigger patterns observed in the analysis across the 26 case companies.

➢ Pattern 1- there is some precedence between the 4 abilities

Across the cases there is some evidence and logic that suggests that efficiency is the critical first step and Internalisation and collaboration are the next steps.

- Efficiency is the first step

There is strong evidence that suggests that most manufacturing practitioners started their sustainability journey by developing the efficiency ability. In specific most companies stated the **ability to see waste** (i.e. non labour) was an important first step in the journey towards efficiency. Seeing waste such as labour and productivity losses is normal in most manufacturing firms (i.e. improving efficiency by managing labour and capital), but seeing wasted energy for example is not. It was repeatedly stated that if a company is able to see non-labour waste, then they are able to start doing something about it (Company C01, C06, C18, C26). Developing the **ability to see environmental and social waste and creatively and systematically reduce them is an important first step in commencing the sustainability improvement journey**.

- Internalisation and collaboration are the next steps

Some companies (example C02, C05, C13, C20) through experimentation and through experience of tackling efficiency improvements, whom did not deliberately set out to find failed value, yet by maturing in their ability to see wastes and tackle eco-efficiency improvements initially, described being able to find failed value in their system and being able to deliberately bring value into their business model that others normally leave outside. Company C02 for example described how it has been able to capture the failed value (i.e. carbon dioxide and heat from its factory), and deliberately bring the failed value into its business model to grow tomatoes. Interalisation that is described as the **ability to see failed value exchanges and deliberately bring them into the business model appears to be a next logical step after efficiency.** Other companies described actively searching for actors with different capability and knowledge being important. Companies that have been able to look outside of their core business and collaborate with others in an unfamiliar area appear to be able to find interesting solutions (Company C15, C03, C20, C19, C02, C26, C10). Collaboration that is described as the **ability to look for new types of collaborators up and down and outside current value chain, this appears to be another next logical step after efficiency**.

➢ Pattern 2: the ability to see waste is a horizontal ability observed across all four abilities

The ability to see waste is observed to be important across all four abilities. Organisations focusing on the efficiency ability describe the importance of developing the ability to see waste (i.e. non-labour - new ways of seeing waste companies C01, C02, C05, C06, C18, C20, C26). As organisations get more effective at identifying these non-labour wastes, and advance to develop the internalisation, collaboration and whole system design ability, the companies are observed to develop the ability to see failed value exchanges (companies C02, C05, C13, C19, C20, C26) across the system. Which is clearly a different form of waste. Developing the ability to 'see waste' is important across all 4 abilities.

➢ Pattern 3: Whole system design ability requires the 3 abilities of efficiency, internalisation and collaboration (i.e. the 4 abilities relate to each other)

- The pattern in the data and logic suggests that, companies cannot do whole system design before understanding the 3 abilities efficiency, internalisation and collaboration. It appears companies can do efficiency, internalisation and collaboration separately, but cannot do whole system design without the other 3.
- Efficiency is stated as the critical first step and organisations need to become effective at being able to see waste. It is observed that organisations that have been able to look for new variables/connections outside the firm boundary have been able to find better solutions to improve industrial sustainability. In most cases, the variable is owned by an actor who is outside the industry i.e. who is an unusual partner. The evidence suggests that collaboration is an important ability for whole system design to be able to make the system boundary bigger. The ability to see failed value exchanges and deliberately bring them into the business model is important for whole system design. The evidence suggests that internalisation is an important ability for whole system design to be able to bring failed value into across the system into the business model to create positive value.
- The 3 abilities efficiency, internalisation and collaboration are therefore important to developing the whole system design ability.

➢ Pattern 4: New start up firms find whole system design easier than big existing firms

- It is observed across the data that the most radical solutions that innovate at the system level arise from start-ups (example company C04) who do not have any infrastructure that they are trying to change. The big established companies (example Company C01) are in many ways the bravest, changing company C01 is harder than changing C04 who are both automobile companies.

- Company C01 is a world leader in its sector in terms of efficiency. That has been able to achieved radical improvements in its resource efficiency; reducing its energy usage per vehicle by over 70%. In the same period it also reduced water use per vehicle by over 75%, and waste produced per vehicle by nearly 70%. But the company is challenged and not so good at whole system design.
- Company C04 being a start-up and had a blank piece of paper to rethink how the company can provide mobility as a business. The company C04 see themselves as not a car manufacturer, but a mobility system that is responding to economic and environmental constraints. The organisation offers an innovative business model where the company sells mobility by charging customers a fee per month and per kilometre, the company then pay for the fuel.
- There might be individual who are good at whole system design in both organisations C01 and C04. But the ability of the start up firm Company C04 to have a blank piece of paper (i.e. 'blank slate'), allows it to challenge existing systems and think how to do better. This is harder for Company C01 to do as it has got over 75 years of history and investment tied up.
- Company C04 has a vision to produce mobility at zero cost to the planet by developing a business model around sale of service and whole system design.

➢ Pattern 5: Organised learning

The researcher suggests that organisations can get some understanding of what they need to be good at from education and awareness, but cannot get the ability from standard education. It is observed that organisations have to use their understanding to generate the ability (i.e. learning by doing makes the abilities come alive). In some companies these are seen as some how accidently learnt abilities, it is unplanned (company C02, C20). And it is going to take others a long time to get good at this, exactly because it's unplanned. Some companies think and state you have to recruit really skilled people to make sustainability improvements. The evidence in this research argues these 'abilities' can be learned. Therefore organisations can build a learning programme. Organisations can develop these abilities, as apposed to recruiting clever people/sustainability specialist. Companies such as C02, C05, C13, C20 described they have been able to develop this ability over time through a culture

of **experimenting and learning by doing** (e.g. Its about learning, its about using pilots. Its about the process, you have to try things)**.** Most organisations described **encouraging new ideas** (e.g. challenging and finding better ways to do something) **and supporting the implementation of new initiatives being important** to developing the ability to discover failed value.

➢ Patter 6: Innovative business models through the concept of failed value exchange

Organisations that understand the logic and concept of failed value exchange are observed to be able to deliberately bring activities and value into the business model that others leave outside. These organisations are observed to be able to find opportunities for internalising costs and transforming them to value, enabling creation of new business models and new value forms (Company C15, C03, C20, C19, C02, C26, C10).

Discovering failed value types in the network

- Type A: I give, but don't get a return (e.g. Company X gives cleaner water after production, but does not get a return)
- Type B: I give but you don't want (e.g. company X gives carbon dioxide and heat to the planet and neighbours that they don't want)
- Type C: I don't give but you want (e.g. Customer X wants longer lasting and durable product but is not getting it from Brand Y. A business might be missing an opportunity to capture value.)
- Type D: I have too much (or give) (e.g. company X produces alot of by-product Y, this can captured and used for another process Z)

Organisations that understand where the value exchanges fail with its stakeholders in the system appear to be able to capture a lot of value opportunities, and this concept is observed to support business model innovation for sustainability (i.e. re-thinking the value proposition).

10.2 Industrial sustainability ability framework

The research was conducted to better understand, what abilities do companies need to improve their industrial sustainability. The four abilities of efficiency, internalisation, collaboration and whole system design are identified from across 26 case companies. Bringing the 4 abilities (themes) that include sub-themes together the researcher proposes the industrial sustainability ability framework (Figure 11).

- Efficiency: ability to see environmental and social waste and creatively and systematically reduce them.
- Internalistation: ability to see failed value exchanges and deliberately bring them into the business model.
- Collaboration: ability to look for new types of collaborators up and down and outside current value chain.
- Whole system design: ability to find advantageous connections across the system.

The framework represents a novel way of understanding and examining abilities for improving industrial sustainability. These 4 abilities are observed to aid the development of next-generation sustainable factories and transformation towards a more sustainable industrial system. The framework contributes to understanding what abilities do companies need to improve their industrial sustainability. Manufacturing practitioners and academics can use the framework to understanding what do companies need to be good at and diagnose, identify and then prioritise long-term ability development for industrial sustainability.

Figure 11. Industrial sustainability ability framework

Chapter 11
Conclusion

The chapter presents a summary of the key contributions to knowledge, the strengths and weakness of the research, the recommendations for future research, the contributions to practitioners and other academics are presented.

11.1 Contributions to knowledge

The primary contribution of this research is to the field of industrial sustainability. This study makes a significant contribution that addresses an under-researched aspect of what abilities do companies need to improve their industrial sustainability. The research provides understanding of abilities that might be needed to transform from todays position towards a more sustainable industrial system. The research uncovers 4 abilities of efficiency, internalisation, collaboration and whole system design identified in this research that can be used by companies to improve their industrial sustainability. This is not a complete list, however it is novel and the abilities proposed is a new way of doing things that is not described and looked at in the same way in existing literature. The primary focus of the contribution has been geared towards the field of Industrial Sustainability. However, the research simultaneously contributes to a wider body of literature associated with sustainable business models, competencies and abilities.

This research has contributed to knowledge by answering the following research question.

Research question

- What abilities do companies need to improve their industrial sustainability.

The research is based on data collected in 26 organisations; representing 12 sectors (Automobile, Aerospace, FMCG, Retail, Clothing, Footwear, Carpets, Craft, Furniture, Food and Beverage, Packaging, Ejection seats), companies from 8 countries (United Kingdom, United States of America, Germany, India, Sri Lanka, Vietnam, Spain), and 162 participants in total out of which 70 are in senior

management positions, some director level or above. The four abilities were identified from the case study data in the exploratory stage of the research, which was further investigated in the descriptive stage of the research to confirm and improving the validity of the findings. The 4 abilities identified in this research are efficiency, internalisation, collaboration and whole system design. This research has addressed a literature gap and met an industrial need. The results of the study led to the formation of the framework. Bringing the 4 abilities (themes) that include 9 sub-themes together the researcher proposes the industrial sustainability ability framework (Figure 11).

The findings of this research are:

Efficiency theme (A)- Ability to see environmental and social waste and creatively and systematically reduce them.

- **Sub-theme (A1)-** ability to see environmental and social waste.
  - Being able to see waste,
  - Being able to be physically present at the location.
- **Sub-theme (A2)-** ability to find creative solutions for environmental and social waste.
  - Being able to experiment,
  - Being able to learn by doing.
- **Sub-theme (A3)-** ability to identify improvements in a systematic way and make it routine.
  - Being able to develop routines,
  - Being able to share best practices across sites,
  - Being able to standardise practices,
  - Being able to develop shared long term-vision,
  - Being able to set challenging environmental and social targets,
  - Being able to find the fundamental minimum,
  - Being able to solve problems using lateral thinking,
  - Being able to develop the ability to identify root causes.

The literature and current understanding on resource efficiency emphasises the importance of using resources with care, presenting examples of operational best practices, strategies and tactics for non-labour resource efficiency in factories

(example Von Weizsacker et al., 1997; Esty et al., 2009; Lovins, 2011; Despeisse et al., 2011). Authors highlight the importance of being able to find and implement resource productivity improvements (Von Weizsacker et al., 1997; Esty et al., 2009; Lovins, 2011; Despeisse et al., 2011), being able to learn from other companies (Bocken et al., 2013; Ball et al., 2009), being able to measure and improve the energy and material used (Ameling et al., 2010; Mackay, 2008; Bunse et al., 2011; Allwood, 2012; Duflou et al., 2012) and being able to continuously find improvements (Despeisse et al., 2015; Litos and Evans, 2015). But no authors were found that studied the specific ability needed to deliver resource efficiency and industrial sustainability.

The findings (Efficiency theme A) emphasise the importance of the abilities; A1- ability to see environmental and social waste, A2- ability to find creative solutions for environmental and social waste, and A3- ability to identify improvements in a systematic way and make it routine. The sub-theme (A1, A2, A3) is compared against existing literature to illustrate novelty and contribution to knowledge. For example much of the literature on the Japanese production system talks about 'seeing waste' (i.e. labour waste) (Ohno, 1988; Liker, 2004). The research finding sub-theme A1 is referring to a different type of waste (i.e. non-labour waste) to the main literature, and no authors were found that studied the ability needed to deliver resource efficiency. The authors (Zokaei et al., 2013) use case studies to provide understanding of the challenges, opportunities, tools and techniques that can be used in the path to becoming lean and green; but an ability-based view is not discussed. The findings of (Efficiency theme A) provide empirical evidence and understanding of the abilities (sub-theme A1, A2 & A3) companies need to improve their resource efficiency and industrial sustainability.

Internalisation theme (B) - Ability to see failed value exchanges and deliberately bring them into the business model.

- **Sub-theme (B1) -** ability to see failed value exchanges.
    - Being able to see and discover failed value exchanges across the current system and the firms network of stakeholders,
    - Being able to discover failed value types in the network,

- Type A (I give, but don't get a return)
- Type B (I give, but you don't want)
- Type C (I don't give but you want)
- Type D (I have too much)

- **Sub-theme (B2)** - ability to creatively transform failed value into positive value and bring it into the business model.
  - Being able to encourage new ideas and supporting the implementation of new initiatives,
  - Being able to bring more value under your control by linking your knowledge to your benefit,
  - Being able to redesign the business model.

The literature and current understanding on sustainable business models emphasises the importance of the concept of value proposition and the creation of creative positive benefits to its stakeholders, and provide conceptual understanding of the need for system transformation and value transformation. An ability-based view is not presented. Authors in the literature reviewed do not present an ability-based view or use that word or any synonyms. Authors highlights the importance of being able to innovate and transform business models to create sustainable value (Adams et al., 2016; Bocken et al., 2014), being able to capture value (Bocken et al., 2014; Teece, 2010; Boons and Leudeke- Freund, 2013), being able to improve resource efficiency (Bocken et al., 2014; Boons & Lüdeke-Freund, 2013) and being able to shift from providing products to providing services (Tukker, 2015). Little knowledge and understanding is offered about specific abilities needed to deliver sustainable business models and industrial sustainability.

The findings (Internalisation theme B) emphasise the importance of developing the abilities; B1- ability to see failed value exchanges & B2 - ability to creatively transform failed value into positive value and bring it into the business model. The sub-theme (B1 & B2) is compared against existing literature to illustrate novelty and contribution to knowledge. Both sub-themes receive little clear attention in the literature, though many authors write about related concepts. The concept of value exchange is referred to in the Sustainable business models literature; include closed-

loop business models (Wells and Seitz, 2005; Kraaijenhagen et al., 2016), 'Natural Capitalism' (Hawken et al., 2005), social enterprises (Grassl, 2012), Product Service Systems (PSS) (Tukker et al., 2015) and new economy concepts (e.g. Blue Economy; Pauli, 2010). A few authors have sought to unify the various examples in literature and practice in a useful categorisation under the over-arching theme of business model innovation (Boons et al., 2013). Very few authors have contributed towards understanding the creation of new systems and generating value across the value network in the sustainable business models literature by identifying failed value exchanges. Rana et al. (2013) and Bocken et al. (2014) are some of the authors that come closest in their comments to describing failed value exchanges approach and providing an understanding to the concept of sustainable value creation and failed value exchange logic. However, none of the above researchers present an ability-based understanding towards seeing failed value exchanges in their system. The findings of (Internalisation theme B) provide empirical evidence and understanding of abilities (sub-theme B1 & B2) companies need to improve their business model for industrial sustainability.

Collaboration theme (C) - ability to look for new types of collaborators up and down and outside the current value chain.

- **Sub-theme (C1) –** ability to foster and nurture collaboration.
  - Being able to develop a shared vision,
  - Being able to create mutual learning,
  - Being able to develop trust between the partners,
  - Being able to create pre-competitive space,
  - Being able to foster best practice and knowledge sharing.
- **Sub-theme (C2) –** ability to look for new types of collaborators across the firm boundary.
  - Being able to look outside core business and collaborate with others in an unfamiliar area,
  - Being able to actively search for new actors with different capability and knowledge,
  - Being able to interact with non-traditional companies.

The literature and current understanding on concept of industrial sustainability such as Cradle-to-Cradle concept and industrial ecology emphasises the importance of separating and identifying the biological and technical nutrient flow, and may provide a set of design rules, for example it encourages a lot of thought on pairing up with other actors and organisations and matching material flows. The concepts emphasise the mental model challenge and the need and importance of shifting from the current industrial system towards a more sustainable industrial system. Authors highlights the importance of being able to improve resource efficiency and being able to find new collaborators, and being able to exchange waste (Ehrenfield, 2008; McDonough & Braungart, 2002; Despeisse, et al., 2012). But no authors were found that studied the specific ability needed to deliver resource efficiency and industrial sustainability.

The findings (Collaboration theme C) emphasise the importance of the abilities; C1- ability to look for new types of collaborators up and down and outside the current value chain and C2 - ability to look for new types of collaborators across the firm boundary. The authors (Erin, 2015; Edmondson, 2012; Holmes and Smart 2009; Senge et al., 2008) have come closest in their comments to describing the importance of collaboration across organisations. Senge et al. (2008) states that accelerating change in critical systems that shape our future requires networks of collaboration and knowledge. The authors (Edmondson, 2012; Senge et al., 2008) highlight the benefit of the potential to combine resources, skills and knowledge from a wide range of stakeholders to address the challenges of creating a sustainable planet. Authors such as (Edmondson, 2012; Senge et al., 2008) describe addressing problems that are too complex for a single organisation to address, highlighting a growing number of projects involve collaboration among partners from different firms and industries. The findings of (Collaboration theme C) provide empirical evidence and understanding of abilities (sub-theme C1 & C2) companies need to improve their industrial sustainability.

Whole system design theme (D)- ability to find advantageous connections across the system.

- **Sub-theme (D1) –** ability to make the system bigger to uncover new solution opportunities.

- Being able to set and broaden the system boundary,
- Being able to use actor and relationship mapping,
- Being able to skillfully co-create a shared vision of the future,
- Being able to look outside current business and finding new partners and connections.

- **Sub-theme (D2) –** ability to look for key interdependencies where greater impact can be achieved.
  - Being able to find points of best leverage (i.e. win-win, positive feedback),
  - Being able to prioritise effort/intervention,
  - Being able to find new connections outside the firm boundary.

The literature and current understanding on system thinking, whole system design and systems innovation emphasises the importance of being able to take a long-term view towards industrial sustainability (Senge, 2008), being able to understand the relationship between the industry and ecosystems (Anarow et al., 2003), being able to redesign the industrial system (Rocky Mountain Institute-RMI, 2006; Hawken et al., 1999; Charter et al., 2008), being able to find opportunity for radical resource efficiency at system-level (Schaltegger and Wagner, 2011), being able to find advantageous interactions (Meadows and Wright, 2009; Madrazo and Senge, 2011) and being able to see the bigger picture (Senge, 2008). But no authors were found that studied the specific ability needed to deliver industrial sustainability at system-level, with (Senge, 2008) being a notable exception contributing to understanding the un-healthiness of the world today by linking this to our inability to see it as a whole and to see the interdependence between systems.

The findings (whole system design theme D) emphasise the importance of the abilities; D1- ability to make the system bigger to uncover new solution opportunities) and D2- ability to look for key interdependencies where greater impact can be achieved. The authors (Senge, 2008; Anarow et al., 2003; Charnley et al., 2011; Cabrera et al., 2015) have come closest in their comments to describing the importance a systems thinking approach, in identifying and understanding connections, exchanges, and interactions between stakeholders. The data agrees with this literature and provides empirical evidence on how organisations are developing

the ability (D1 and D2). The findings of (Whole system design theme D) provide empirical evidence and understanding of abilities (sub-theme D1 & D2) companies need to improve their industrial sustainability.

The 4 abilities identified are novel; previous research has often not been based on an ability-based view to improve industrial sustainability, and no authors have presented the 4 abilities together. The findings described have been compared against literature to show newness and contribution.

The efficiency ability discussed in this research refers to individual-level abilities. Both the efficiency and internalisation abilities refer to individuals in the organisation being able to specifically develop the ability to see environmental and social waste (e.g. efficiency ability) and develop the ability to see failed value exchanges (e.g. internalisation ability). The collaboration and whole system design ability however, can be described as organisational and system level abilities as in the ability to find advantageous connections across the system (e.g. whole system design ability) or ability to look for new types of collaborators up and down and outside the current value chain (e.g. collaboration ability). These are organisational level abilities. The evidence from the case studies describes in some instance how individuals and some instances how organisations are developing these abilities, there is some difficulty in describing and distinguishing what is individual, organisational and system level abilities and this is one of the limitations and nature of this research.

11.2 Reflection on strength and weaknesses of the research

This section reflects on strengths and weaknesses of the research

➢ Strengths

- The case companies selected were either world leading or advanced in their sustainability performance within their sectors. The cases were selected to come from different sectors. All have very clear and publically acknowledged leadership in sustainability within their sector. The research is based on data collected in 26 organisations. The conducted cross-industry case studies and high-

profile focus groups have provided richness of data, and provided valuable information and insights to this the research.

- Triangulation was designed into the research to improve the research quality.
- Generalisation was sought as the data emerges from findings from across 26 case companies across 12 different sectors and 162 participants.
- Reliability is sought by illustrating how sense was made from the raw data in the research methods (i.e. research analysis in the exploratory and descriptive stages of the research).

➢ Weaknesses

The research approach followed was qualitative and the research method was based on multiple methods for data collection. One of the limitation of qualitative research is the difficulty for other researchers to replicate this study and the obtained results, which cannot be achieved as easily as when adopting a quantitative methodology. Therefore, the author has made every attempt to ensure transparency and rigour of the research.

In the research 4 abilities that were interesting and had strong supporting evidence have been explored in this research, more can be made from the data collected in this research.

It should be recognised that these limitations also represent opportunities for further research.

11.3 Recommendations for future research

The findings of this research contribute to understanding what abilities do companies need to improve their industrial sustainability, the four abilities identified and explored in this research lay the foundations for potential future work. The following is a list of areas with potential for further research identified by the researcher:

- How might manufacturers develop and plan a sustainability-training program based on these abilities?
- What works and what does not work in specific industries?

- What other abilities do companies need to be good at?

11.4 Research contributions to practitioners

The presentation of this research findings to senior academics and industrial partners, has led the researcher to conclude that the proposed four abilities are useful and new within the industrial sustainability field. Practitioners could benefit from the knowledge of the abilities identified in this research, as it will aid organisations to challenge existing ways they operate and encourage organisations to develop the abilities found in this research. It seems organisations that are interested in creating a more cleaner and more sustainable industrial system can use the abilities.

The framework represents a novel way of understanding and examining abilities for improving industrial sustainability. The 4 abilities efficiency, internalisation, collaboration and whole system design are observed to aid the development of next-generation sustainable factories and transformation towards a more sustainable industrial system. The framework contributes to understanding what abilities do companies need to improve their industrial sustainability. Manufacturing practitioners can use the framework to understanding what they need to be good at, and to diagnose and identify and then prioritise long-term ability development.

The research findings and industrial sustainability ability framework have already been used with industry collaborators of the Centre for Industrial Sustainability-IfM to develop training programs and facilitate workshop for practitioners interested in improving their industrial sustainability (refer appendix 5).

11.5 Research contributions to other academics

The industrial sustainability ability framework can be used by academics for research and for education purposes. This study enhances cross-disciplinary research with significance for practice, and can instigate discussion among academics from individual disciplines. Academics can use the framework as a tool for debate. The framework can be used to create a common ground for understanding abilities for industrial sustainability, and can prompt discussion on abilities that might be needed

to transform from todays position towards a more sustainable industrial system. It can also further dialogue between academics and practitioners on the subject of abilities for industrial sustainability. Furthermore, academics and practitioners can identify parts of the framework, which can form new research areas.

11.6 Chapter summary

This chapter demonstrates that the research question has been addressed. A reflection on the strengths and weakness of the research and the recommendations for future research is presented. The contributions of the research for practice and research are reinforced to the reader.

Appendix 1. Company C20 examples

1.1.Ability to see environmental and social waste (Aerial drying jeans)

Figure 12. Company C20 Aerial drying jeans - site visit

"For every pair of jeans another competitor laundry washes, we wash 23.3 jeans. A traditional laundry of the same size, producing 350,000 to 400,000 units per month, would normally use 600,000 litres of water daily. The new [company name] laundry uses 600,000 litres, only on the first day of operation, and every day after uses 30,000 litres. This is possible because [Company name] recycles 95% of its water. Solar panels blanket the roof of the building and supply renewable energy throughout the facility. The warm panels are used to heat water…. The Jeans are dried using ***recycled heat*** *from machines…. chemicals were selected and implemented that* ***could dye garment at room temperature***, ***eliminating the need to use energy to heat water.****..We also* ***aerial-dry our jeans,*** *our competitors don't do most of this…why use electricity and an industrial drier to generate heat, when the surrounding temperature is 35^{o}c…****ingenious thinking and thinking out of the box helped us find these solutions.****"*

Source: *Company C20, workshop participant, transcript page 55*

1.2 Ability to see failed value exchanges (Shoe uppers made from off-cut denim trouser waste and then supporting an orphanage)

Figure 13. Shoe uppers are made from off-cut denim trouser waste - site visit

" [Company X] have teamed up with us [Company Name] denim factory to launch a new collection of sustainably made shoes…The shoe uppers are made from off-cut denim trouser waste that would normally have gone to waste... Through this initiative we are able to give back to the community… 100% of the profits from this initiative go to the orphanage… the company, planet and society benefit… We saw an opportunity to demonstrate the big idea of one thing being re-cut into something new without there being any waste and create more value …The orphanage is home to approximately 136 children from newborns up to 16 years old. The profits will be used to provide education, meals and medical care for the children."

Source: *Company C20, workshop participant, transcript page 55*

Appendix 2. Company C02 examples

2.1 Ability to see failed value exchanges (creative use of the waste streams)

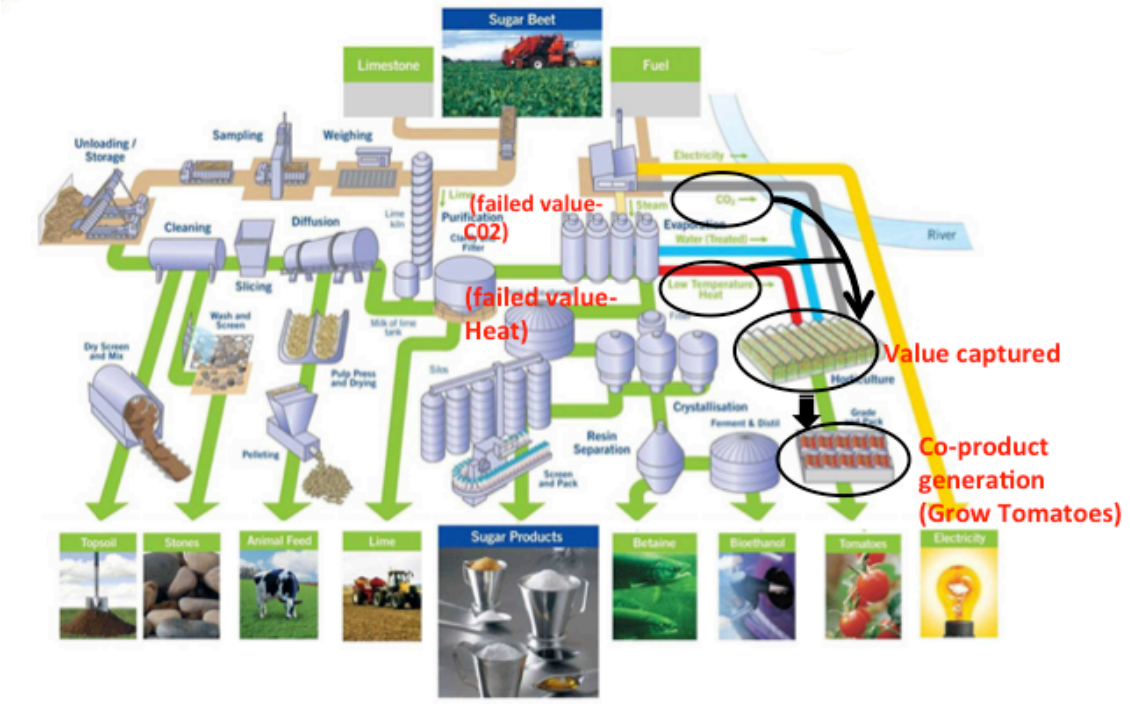


Figure 14. Company C02 ability to see failed value exchanges

"We are the world's largest refinery producing 420,000 tonnes of Sugar annually…We been able ***to find opportunities in our process to produce co-products from the waste streams of the primary sugar production processes****… (Symbiotic co-product lines)….We have found a broad range of additional synergistic and profitable product lines… animal feed, electricity, tomatoes, and bioethanol….More than two hundred and forty miles of piping carries hot water from the factory's Combined Heat and Power (CHP) plant around the glasshouse, to maintain the balmy temperatures, which suit tomato plants.* ***This hot water would otherwise be destined for cooling towers, so the scheme ensures that the heat is used productively…. carbon dioxide as a by-product from the CHP boiler is pumped into the enormous glasshouse to be absorbed by the plants (rather than vented into the atmosphere as waste emissions)….****waste carbon dioxide from the factory is used by tomatoes for photosynthesis… the site also harvests the rainwater from the giant glasshouse roof; over 115 million litres are collected annually to irrigate the plants…the horticulture business produces around* ***140 million 'eco-friendly' tomatoes each year…co-***

product generated by finding opportunities for productive, and creative use of the waste streams….*The heated atmosphere of 4 times ambient levels of CO2 enables the tomatoes to grow at twice the usual rate, providing high productivity for the glasshouse investment."*

Source: Company C02, Interviewee 2B- Head of Engineering, transcript page 8

2.2 Ability to see environmental and social waste

"Champions and employees are empowered to find efficiency and waste reduction improvements continuously…(waste nothing culture)…the culture of doing more with less is reinforced with employee suggestion and reward schemes … employees across the organisation identify efficiency improvements and systematically eliminate waste continuously…. We encourage sharing of best practices across group companies.. (company name) has systematically identified ways to turn waste streams and emissions from our sugar production processes into useful and positive inputs to new product lines."

Source: Company C02, Interviewee 2B- Head of Engineering, transcript page 8

2.3 Ability to look for new types of collaborators across and outside the firm boundary

"Collaboration with suppliers has been a hallmark of many of the improvements…from working with farmers to improve yield, optimise fertilizer use and extend the producing season…. collaborating with [Name of Engine Manufacturer] to optimise the operation of CHP gas turbine... careful consideration of when to partner, when to bring expertise in, and when to outsource new co-product operations has also underpinned the development of new lines of business…."

Source: Company C02, Interviewee 2B- Head of Engineering, transcript page 9

Appendix 3. Company C13 examples

3.1 Ability to see environmental and social waste (waste leather off-cuts to rugs)

Figure 15. Company C13 creatively and systematically reducing waste (waste *leather off-cuts* to rugs)

"We collect more than fifteen materials that go to landfill, always ***seeking a permanent solution for that particular material problem****. Many of our materials are found as we hunt through landfills, industrial estates, or form unique commercial partnerships to help our partners with their waste issues…* ***We use creativity in finding and designing solutions for this problem****… the pieces we make have to make* ***the best possible use of and create the most value from the raw materials (waste)*** *this is how we honour them… We work backwards, so we start with the material. We look at how much there is, what it can do* ***and how we might be able to work with it. What are its limits, its realities****… Then we think about what we could make, what that might cost, and what potential market might be suitable. After this research we prototype and test products at length before launch... Our recent project is with finest quality leather off-cuts…Our leather partners cherish their hides, the waste they produce is in small* ***seemingly unusable pieces****…* ***We found a creative modular design approach as a solution to use this waste****. We created three shapes that can interlock with infinite potential. The three shapes can help make things like rugs that can be remade, and reinvented through time…"*

Source: Company C13, Interviewee 13A-Founder & Owner, transcript page 37.

3.2Ability to see failed value exchanges (waste fire horse to designer bags).

Figure 16. Company C13 creatively and systematically reducing waste *(waste fire horse to designer bags)*

"I've been passionate about waste for years, I want to add value to waste and build a valuable product from it…The adventure started on an auditing course to learn more about ISO 14001 the environmental management standard, where I met members of the [Company Name]. They told me about their disused fire hoses, which cannot be traditionally recycled. I asked to see some and they took me to their fire hose assessment site…There were coils and coils of it piled on the rooftop... landfill is completely inappropriate end for such a heroic material…Some might struggle to see how old fire hoses could be beautiful, but When you polish it and see the lustrous red rubber it becomes this fantastic material.. taking all of it and transforming the fire hoses into something that could have a second life at least as long and useful as its first was the goal…the fire hoses was designed to survive fires and was waterproof, all of which make it a great alternative to leather...we decided that the products we design too must be built to last...we used our imagination to find sustainable ways to rescue the decommissioned fire hoses, we figured out what we could make from it…If a use couldn't be found for the fire hoses most of it would go to landfill…. we been experimenting fire hoses for a while…months of experimenting to figure out how best to manipulate and re-purpose it...A lengthy process of trial and error ensued…we made the fire hoses into roof tiles, furniture, Christmas ornaments… and finally belts…today the designer crafted belts, bags, and accessories are sold in the world's most luxurious department store.. 50% of all profit from sales is donated to charities associated with the wastes used."

Source: Company C13, Interviewee 13A-Founder & Owner, transcript page 38

Appendix 4. Company C04 examples

4.1 Ability to find advantageous connections across the system (selling mobility as a service)

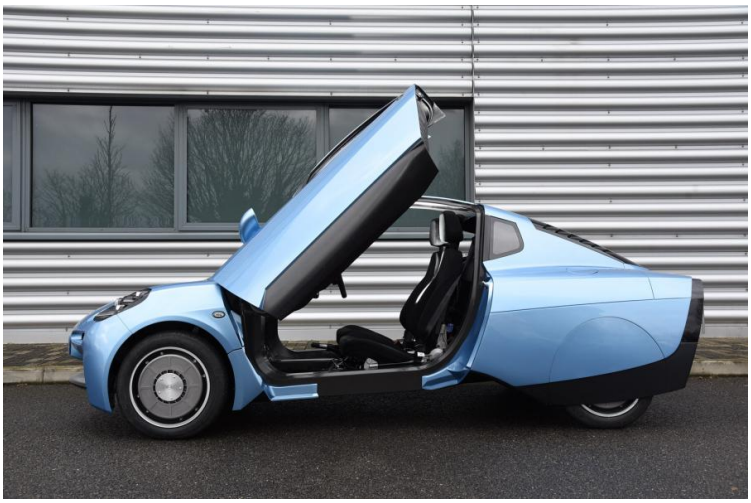


Figure 17. Company C04 selling mobility as a service

Company C04 is a SME automobile company that aims to produce mobility at zero cost to the planet. The company describes a business model, where the company sells mobility to driver and they (i.e. the company) pay for the fuel. It is win-win and a positive feedback loop because, it incentives company C04 to put in technology that customer would otherwise not pay for if they were buying the car. The case company offers an example of **how it has found advantageous connections across the system** and demonstrates maturity in the whole systems design ability (i.e. design of a vehicle system providing mobility as a service). The company describes, "*If you are motivated to sell new cars, you become less inclined, for example, to use the most durable materials. The [name of Company] have coined the phrase '**selling mobility as a service**' cars are offered as part of a service contract. At a result, designing cars of **excellent and lasting quality becomes good business sense**; whilst the unsustainable practice of 'designing for obsolescence' deliberately designing cars that the customer will soon wish to replace becomes a thing of the past".* The company offers an example of how it has **found advantageous connections across the system** and illustrates maturity in the whole systems design ability. The car company, by taking a systems view, internalised the fuel cost, the company pays for

the fuel and customer the distance travelled. The car company by taking a systems view has been able to identify a key **interdependencies that drive system performance**. The company is **able to look for win-win interactions in a system,** and has identified and focused its efforts on making the car light. Company C04 describes*"...this then resulted in a lighter engine needed because it is a smaller car, then the brakes needed to be less powerful, because the car was less heavy, then the requirement was you can put less fuel in it. The petrol tank gets smaller and lighter. If everything gets lighter, you can make the engine light because it needs to move less metal*" this is an example of a win-win interaction and positive feedback. In C04 it is clear that extensive management effort has been focused on taking a systems view and identifying the best leverage point in the planning process of developing the companies business model of producing mobility at zero cost to the planet.

Source: Company C04, *Interviewee 4A - Chief Engineer, transcript page 16.*

Appendix 5. Framework used with industry collaborators

The research findings and Industrial Sustainability Ability Framework have already been used with industry collaborators of the Centre for Industrial Sustainability-IfM to develop training programs and facilitate workshop for practitioners interested in improving their industrial sustainability.

5.1 Ambitious Industrial sustainability ability training program development

The Industrial Sustainability Ability Framework has been identified to be used to develop an ambitious training program to help create a benchmark 60,000 staff industrial park within a vertical end-to-end textile and clothing-manufacturing park in India to improve industrial sustainability to deliver world-class performance.

Figure 18. Company C23 Site visit.

More Information available at:

http://www.industrialsustainability.org/media/60229-EPSRC_Centre_for_Industrial_Sustainability_AR_2014-2015.pdf

5.2 Develop a platform to teach industrial sustainability (develop abilities across the workforce)

The Industrial Sustainability Ability Framework has been used in a workshop at a jeans manufacturing plant in Vietnam. The framework is found to be useful and trigger ideas for finding opportunities for sustainability improvement. The framework and research has been identified to be used in the future in collaboration with the researcher, to develop a platform to teach the abilities to the company employees and then to the rest of the clothing and footwear sector. The industrial sustainability abilities teaching platform will be used to educate the industry to transform from todays position towards a more sustainable industrial system.

Figure 19. Company C20 Site visit.

5.3 Business model transformations for sustainability

The Industrial Sustainability Ability Framework has been used at Company C26, a food and apparel packaging and labeling company based in Sri Lanka, to develop the abilities in the organisation to identify failed value exchanges and create new value to improve their industrial sustainability. The ability framework is described to encourage radical systems innovation (e.g. add greater value while using less energy, water and materials) and business model transformations for sustainability (e.g. finding new value).

Figure 20. Company C26 Site visit.

Appendix 6. Exploratory & descriptive stage interview questions

Exploratory stage 1 interview questions

- Firstly the researcher explains the aim and objectives of the research

Questions:
- What is your background and role in the organisation?
- What are your areas of expertise and responsibility?
- What is your company doing to improve industrial sustainability?
- How are they doing it?
- What do companies need to be good at to improve industrial sustainability?
- What abilities do companies need to improve industrial sustainability?

Descriptive stage 2 interview questions

- Firstly the researcher introduces the 4 abilities (Efficiency, Internalisation, Collaboration, Whole system design) proposed

Questions:
- What are you doing to improve your industrial sustainability?
- Where are you now?
- What do you need to be good at?
- Where do you want to be in the future?
- What matched and what didn't match and what might be missing?

Appendix 7. How data was coded exploratory & descriptive stage

The analysis followed two stages – exploratory stage & descriptive stage. In this section examples are presented to illustrate how the data collected was coded during the analysis.

Exploratory stage data analysis

How the quote selection, clustering and coding was done

- Quote selection

This section describes quote selection from the transcripts.

The analysis was conducted by firstly reading through the interview transcripts from stage one data collection (example transcript extracts Case Company C01- Automobile Manufacturer, Case Company C02- FMCG Manufacturer are given in Table 13 and 14 below page 194). The researcher sought patterns within the data of what companies are doing to improve their industrial sustainability, and what abilities do companies need to improve their industrial sustainability. Those quotes that provided direct responses or evidence in answering the research question were highlighted immediately, in addition specific quotes that addressed the more general research objectives were also highlighted, as were any quotes with specific emphasis from the interviewee (e.g. assertions - interviewee used strong adjectives such as *'this is important', 'the key point', 'critical', 'we put a lot of effort into this', 'exciting', 'big'*) this was noted and taken into account to reflect their relative importance during the analysis.

Example of a **highlighted quote** from a transcript:

"...You can only tell by actually going to the place where that process has worked, to understand how it is operating. We call this 'genchi genbutsu'- 'go, see and study'. And more importantly go and talk to the people who are operating those processes on a daily basis. They are the experts; the engineers are not the experts in this case. You cannot understand a process by sitting in your office. You have to go out there and understand the process…. And making things visible is one of the key points"(Company C01, Interviewee 1A- General Manager for Environmental Affairs and Corporate Citizenship, transcript page 3).

- **Clustering of quotes**

This section describes the clustering of the highlighted quotes.

The highlighted quotes from the transcripts that were similar were clustered together. This was done by the researcher firstly taking one quote one interviewee describing the importance of "*making things visible is one of the key points…"(Company C01)* and using that quote to look and find other similar quotes for example.

The highlighted quotes that were similar were grouped together *e.g. "seen opportunities for improvement…."(Company C02), "identify waste…."(Company C03), "see the waste in the process…."(Company C02), "go and see…."(Company C01).*

- **Coding and naming the code**

This section describes the how the codes were named.

The highlighted clusters of quotes were then given a code by bringing each cluster of quotes together in one place and then gave a name to it. Example of the codes generated from the transcripts is illustrated in table 12 & 13 below. For example the code 'sharing learning' means the highlighted texts represent some descriptions of inter-organisations learning and organisations sharing learning across the organisation. These codes describe the ideas/pattern represented by pieces of text highlighted in the transcript.

For example the group of similar quotes "seen opportunities for improvement*….(Company C02)", "identify waste…….(Company C03)", "see the waste in the process…….(Company C02)", "go and see……..(Company C01)")* was gathered and the researcher chose to give this group of quotes the code 'making things visible'

This section highlights how the qualitative data obtained from interview transcripts and observations was organised by coding

Case C01 transcript text – Example *(Company C01, Interviewee 1A- General Manager for Environmental Affairs and Corporate Citizenship, extracts from transcript page 1-4).*	Codes
"*To take people along with you, you have to create a vision…. Used 'guiding principles' and **'set challenging targets'** to continually reduce environmental impact and disseminate this to all levels of each manufacturing plant….The aim is that the whole company should be green, clean and lean. The company's aim is to move towards a net positive impact rather than just trying to reduce negative factors to zero. Take the UK plant for example; in 1993 we said we wanted to go **zero waste to landfill** at the UK Plant. We gave ourselves five years to do it and whilst believed it was attainable we had no clear idea how we were going to get there…Resource efficiency has been important….between 1993 and 2013 we have been able to reduce the energy usage per vehicle by over 70%, Water use per vehicle by over 75%, and waste produced per vehicle by nearly 70% and achieve zero waste to landfill.... To continue to find ways to improve and tackle resource efficiency energy, water, waste.....You need to know what the current situation is. For example, what is the current situation...You can only tell by actually going to the place where that process has worked, to understand how it is operating. We call this 'genchi genbutsu'- **'go, see and study'**. And more importantly go and talk to the people who are operating those processes on a daily basis. They are the experts; the engineers are not the experts in this case. You cannot understand a process by sitting in your office. You have to go out there and understand the process…. And **making things visible** is one of the key points… looking for opportunities for further kaizen and efficiency gain…Some techniques we use are promote effective **inter-company learning**…two plants generation 1 and 2, architecture is completely different… We wanted plant 1 to compete and catch up with plant 2. And plant 2 to push on new boundaries…One has been working on energy and the other on water… Those were the big challenges at those plants...We instituted a competition using a racing track to plot out the performance of the 10 different shops in the production plant: Paint, Assembly, Power Train, Body Welding, etc. Once a month, the performance of each shop is plotted out on the racetrack, so shop captains can see how they are doing... Instituted a process where experts from one facility examine improvement options at other plants...The key is we share the various different bits of information we are gaining across the organisation...to perform effective Yokoten (sharing) you need a certain number of things... We need a network, a forum/opportunity, mechanism/standardized format, motivation and recognition.... we have 51 manufacturing companies in 27 countries…Have to create an opportunity to share (Forum/opportunity)…we have a Global environment conference, 5 regional so we can share ideas…We also have a Shop by shop activity to develop new ideas and actions (e.g. paint shop).. Where each of the shops will get together from 4 manufacturing sites in Europe that have a paint shop…We will put 4 of the groups together…Give them a leader, they will share information that is specific to their processes…learning across different manufacturing sites is very important…we have set up a '**teach-learn-do-teach' approach,** where in return for **learning** from one factory site, employees need to teach another factory site about what they learned, which encourages **cross-factory learning**…One tool we use to share the knowledge is our own eco-handbook..the handbook has many detailed chapter covering the processes commonly found … booklet and intranet systems provide a hook.. employees will take it away and contact the right people, plan a visit to go and see...these activities help us systematically identify waste and achieve a culture of continuous improvement…We want to be able to improve the performance of older plants and take the newer ones onto a different level"*	Setting ambitious targets Making things visible Sharing learning Sharing learning

Table 12. Case Company C01 Codes

'Setting ambitious targets', 'Making things visible' and **'Sharing learning'** are examples of codes that emerged from the above analysis of the transcript text from case company C01.

Case C02 transcript text – Example *(Company C02, Interviewee 2B- Head of Engineering, extracts from transcript page 8- 9)*	Codes
We are committed to building a long-term, robust and resilient business and to achieving our vision of becoming the world's leading sugar business. To do this, we respond to the many challenges and opportunities that arise from climate and population change while ensuring that ***continuous improvement*** *and operational excellence drive efficiency, allowing us to make the most of every stick of cane and root of beet. We have been focusing our efforts on improving energy efficiency, water use, agricultural productivity and engaging beyond the factory with the wider community and being committed to acting in a socially responsible manner…We are the world's largest refinery producing 420,000 tonnes of Sugar annually…* ***Core business innovation****, We been able to find opportunities in our process to produce co-products from the waste streams of the primary sugar production processes… (Symbiotic co-product lines)….We have found a broad range of additional synergistic and profitable product lines… animal feed, electricity, tomatoes, and bioethanol….More than two hundred and forty miles of piping carries hot water from the factory's Combined Heat and Power (CHP) plant around the glasshouse, to maintain the balmy temperatures, which suit tomato plants. This hot water would otherwise be destined for cooling towers, so the scheme ensures that the heat is used productively…. carbon dioxide a by-product from the CHP boiler is pumped into the enormous glasshouse to be absorbed by the plants (rather than vented into the atmosphere as waste emissions)….waste carbon dioxide from the factory is used by tomatoes for photosynthesis… the site also harvests the rainwater from the giant glasshouse roof; over 115 million litres are collected annually to irrigate the plants…the horticulture business produces around 140 million 'eco-friendly' tomatoes each year…a co-product generated by finding opportunities for productive, and creative use of the waste streams….The heated atmosphere of 4 times ambient levels of CO2 enables the tomatoes to grow at twice the usual rate, providing high productivity for the glasshouse investment. ….those with the process knowledge are empowered to identify innovations to be taken forward to* ***uncover new value opportunities****. We are always looking for people with a can-do attitude and an insuppressibly passion. Natural leaders with tenacity, an enquiring mind and the ability to deliver innovative yet practical solutions. We are interested in individuals who have talent, drive and a real hunger for rapid advancement….****Collaboration*** *with suppliers has been a hallmark of many of the improvements…from working with farmers to improve yield, optimise fertilizer use and extend the producing season…. collaborating with [Name of Engine Manufacturer] to optimise the operation of CHP gas turbine... careful consideration of when to partner, when to bring expertise in, and when to outsource new co-product operations has also underpinned the development of new lines of business…."*	Continuous improvement Innovation Creative use of the waste streams Uncover new value opportunities Collaboration

Table 13. Case Company C02 Codes

'Continuous improvement, 'Innovation', 'Creative use of the waste streams', 'Uncover new value opportunities' and **'Collaboration'** are examples of codes that emerged from the above analysis of the transcript text from case company C02.

Theming and naming of themes

This section highlights how the grouping and the naming of the higher-level themes was done by reviewing the codes from across the cases company (C01 – Automobile manufacturer, Company C02 – FMCG Sugar manufacturer, Company C03 – Clothing Retailer, Company C04 – SME Automobile company).

Theming

The objective was to arrive at the highest-level theme (overarching theme grouping the code names) that represents the key abilities needed for industrial sustainability.

- Preliminary round of theming

The codes that are similar, represented a pattern and had something in common were grouped together. The researcher by grouped all the codes according to some commonality (Group of codes – Theme A, Theme B, Theme C, Theme D, Theme E, and Theme F). For example the group of codes *'setting ambitious targets', 'making things visible', 'sharing learning', 'systematic' and 'continuous improvement'* was grouped together as they all represented a bigger pattern of aiding companies to improve the overall resource efficiency in their organisations and had that in common. This group was called a theme and was then named efficiency by reviewing and identifying the patterns across the codes within the theme. The title of the theme emerged out of the grouped codes.

In the initial stage of analysis similar codes were grouped and formed 6 major themes. In the initial phase of grouping, quotes that represented 'making things visible' was copied and placed in both groups theme A- resource efficiency and theme E- Seeing waste (e.g. copy-coding where one quote hits two themes) thus the researcher copied the quote and place it in both themes A & E.

Theme A All the Resource **Efficiency** related codes	**Theme B** All the **Internalisation** of value related codes	**Theme C** All the **Collaboration** related codes	**Theme D** All the **Whole system design** related codes	**Theme E** All the **Seeing waste** related codes	**Theme F** All the **Innovation** related codes
Example of codes from the grouped Theme A: 'setting ambitious targets', 'making things visible', 'sharing learning', 'systematic', 'continuous improvement'.	Example of codes from the grouped Theme B: 'bring into the business model', 'Creative use of the waste streams', 'Business model innovation', 'missed value', 'capture value', 'uncover new value opportunities'.	Example of codes from the grouped Theme C: 'relationship', 'collaborate', 'pre-competitive', 'new partner', 'collaborate in an unfamiliar area'.	Example of codes from the grouped Theme D: 'System design', 'transform system', 'radical', ' 'long-term view', 'points of leverage'.	Example of codes from the grouped Theme E: 'making things visible'.	Example of codes from the grouped Theme F: 'business model innovation', 'radical improvement', 'value capture to innovate', 'creative'.

Table 14. Preliminary round of coding and grouping - exploratory stage

Final round of theming

- Grouping and naming the themes

During the clustering and naming the group themes, emphasis and effort was put to make sure the names assigned to the overall theme would:

- Accurately reflect what is being observed (e.g. this was done by carefully reading the quotes and codes and then interpreting them).
- Be distinct, with no overlap (e.g. this was done by eliminating repetition (synonyms used) and similar codes (combine) by carefully reading through quotes and grouping similar ideas that had commonality)
- All relevant data should fit into a Theme.

The Researcher during the review of themes (A to E) checked if they followed the

above points (e.g. Are the themes accurate, distinct and relevant). Theme E ('seeing waste') was an accurate theme and relevant to improving industrial sustainability but could not be made distinct from Theme A ('efficiency'). Without being able to see the waste occurring companies couldn't make an efficiency improvement. Similarly Theme F ('innovation') was reviewed and found to occur within the other themes A, B and C and could not be made distinct. In the researchers final judgment the similar themes were combined. The 4 themes in the final round offered a clear separation between the themes and all matched the criteria that the themes should be accurate, distinct and relevant setout in the exploratory stage of analysis.

In the final round of analysis stage 1 exploratory phase, 4 high level themes (Theme A- Resource Efficiency), (Theme B – Internalisation), (Theme C- Collaboration), (Theme D – Whole system design) were confirmed as illustrated in table 15.

Theme A - efficiency **(Patterns of improving** efficiency **related abilities)**	Theme B- Internalisation **(Patterns of** Internalisation **of value related abilities)**	Theme C- collaboration **(Patterns of** collaboration **related abilities)**	Theme D- whole system design **(Patterns of** whole system design **related abilities)**

Table 15. Final grouping and naming of the 4 themes- exploratory stage

In the exploratory phase of the research the codes were used to form these 4 high level themes.

The 4 themes from stage 1 of the data collection were used to build a high level framework linking the themes (i.e. abilities) that was used to structure the stage two data collection.

Descriptive stage data analysis

The objective of the descriptive stage of the research was to gain a deeper insight into the themes proposed in the exploratory stage (Theme A-efficiency, Theme B-Internalisation, Theme C-Collaboration, Theme D- Whole system design). The 4 themes were used as the starting points of analysis in the descriptive stage to confirm, reject or add details to each theme from the exploratory stage. All the interviews and workshop transcripts, supporting documents, and personal notes were analysed and coded according to the themes they represented (e.g. table -16, 17, 18 and 19). For each organisation and workshop the data was studied to confirm, reject or add detail to the 4 themes. New data within each theme was grouped together according to what seemed to have some commonality. From this the sub-themes that make up each of the themes emerged; these were coded as for example (sub-theme A1) (Sub-theme A2), (Sub-theme A3) that make up (Theme A).

Theme A – Efficiency

Examples of extracts from the transcripts are presented for each of the sub-themes A1, A2, A3 in chapter 6. The below table represents the overall clustering and coding for the efficiency theme in the descriptive stage of the analysis table 16.

Sub-theme A1 ability to see environmental and social waste related quotes	**Sub-theme A2** ability to find creative solutions for environmental and social waste related quotes	**Sub-theme A3** ability to identify improvements in a systematic way and make it routine related quotes
Example of codes from the grouped Theme A1: 'see waste', 'seeing', 'finding', 'observe', 'looking', 'searching', 'put on your glasses', 'make things visible', 'present at the location'.	Example of codes from the grouped Theme A2: 'creative-thinking', 'thinking outside the box' and 'ingenious', 'able to experiment', 'learn by doing'.	Example of codes from the grouped Theme A3: 'develop routines', 'share best practices across sites', 'standardise practices', 'develop shared long term-vision', set challenging environmental and social targets', 'find the fundamental minimum', 'identify root causes'.

Table 16. Efficiency theme A and sub-theme codes A1, A2, A3

Theme B – Internalisation

Examples of extracts from the transcripts are presented for each of the sub-themes B1, and B2 in chapter 7. The below table represents the overall clustering and coding for the Internalisation theme in the descriptive stage of the analysis table 17.

Sub-theme B1 ability to see failed value exchanges and deliberately bring them into the business model related quotes	**Sub-theme B2** ability to creatively transform failed value into positive value and bring it into the business model related quotes
Example of codes from the grouped Theme B1: 'see value missed', 'discover failed value exchanges' .	Example of codes from the grouped Theme B2: 'capture new value', 'transform failed value', 'positive value creation', 'bring value into the business model'.

Table 17. Internalisation theme B and sub-theme codes B1, B2

Theme C – Collaboration

Examples of extracts from the transcripts are presented for each of the sub-themes C1, and C2 in chapter 8. The below table represents the overall clustering and coding for the Collaboration theme in the descriptive stage of the analysis table 18.

Sub-theme C1 ability to foster and nurture collaboration related quotes	**Sub-theme C2** ability to look for new types of collaborators across the firm boundary related quotes
Example of codes from the grouped Theme C1: 'develop a shared vision', 'create mutual learning', 'develop trust between the partners', and 'create pre-competitive space ',' foster best practice and knowledge sharing .	Example of codes from the grouped Theme C2: 'look outside core business', 'collaborate with others', 'unfamiliar area', 'actively search for new actors', 'partner with new capability and knowledge', 'interact with non-traditional companies'.

Table 18. Collaboration theme C and sub-theme codes C1, C2

Theme D – Whole system design

Examples of extracts from the transcripts are presented for each of the sub-themes D1, and D2 in chapter 9. The below table represents the overall clustering and coding for the Collaboration theme in the descriptive stage of the analysis table 19.

Sub-theme D1 ability to make the system bigger to uncover new solution opportunities related quotes	**Sub-theme D2** ability to look for key interdependencies where greater impact can be achieved related quotes
Example of codes from the grouped Theme D1: 'set and broaden the system boundary', 'use actor and relationship mapping', 'skillfully co-create a shared vision of the future', 'look outside current business', 'finding new partners', 'new connections'.	Example of codes from the grouped Theme D2: 'find points of best leverage', 'win-win', 'positive feedback loop', 'prioritise effort', 'intervention', 'new connections outside the firm boundary'.

Table 19. Whole system design theme D and sub-theme codes D1, D2

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