Next Manufacturing Revolution

The Next Manufacturing Revolution:

Non-Labour Resource Productivity and its Potential for UK Manufacturing

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Next Manufacturing Revolution founding members:

Lavery Pennell is a strategy advisor assisting clients to unlock value while improving sustainability performance. Using a combination of corporate strategy, commercial, technical and sustainability experience, their rigorous and comprehensive approach creates step-change cost savings, revenue opportunities and competitive advantage. www.laverypennell.com

2degrees is the world's leading business community for driving growth, efficiency and profit through sustainability. It has over 31,000 professional members in more than 90 countries. 2degrees Enterprise Services helps organisations to collaborate using new media to solve their sustainable business challenges; their mission is to make it efficient for retailers and major brands to engage key stakeholders, reduce environmental impacts and grow their businesses. www.2degreesnetwork.com

The Institute for Manufacturing (IfM) is the public face of the University of Cambridge Department of Engineering Manufacturing and Management Division. The IfM takes a distinctive, cross-disciplinary approach, bringing together expertise in management, technology and policy to address the full spectrum of industrial issues. The IfM's activities take place within an unusual structure that integrates research and education with practical application in industry. www.ifm.eng.cam.ac.uk

Forewords

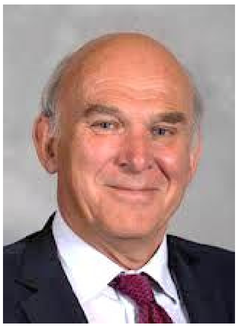
Achieving the continuous improvements in competitiveness necessary for a company to succeed in the modern world can only be achieved by relentless year over year improvements in innovation and all forms of productivity.   So I welcome this report which presents the untapped potential of resource efficiency for UK manufacturing.   This is a subject that has not received the wide attention that it deserves, given its low risk potential to boost profits while improving the sustainability of manufacturing.

Continuous improvement in resource efficiency has been something that I have long championed in the companies with which I have been involved – and which has rewarded those organisations with strong performance improvements.   Yield improvements are a natural place for manufacturing organization to focus. For example, at 3M, millions of tonnes of material have been saved or reprocessed over the years as the company focused steadily on driving yield improvements. While not the focus of this report, the consequent reductions in capital expenditure, energy saving and emissions reduction were huge.

The Next Manufacturing Revolution founders are driving better awareness around non-labour resource productivity, showing us the potential that is being missed, using real case studies. They have also developed an engagement programme for manufacturers, the individuals who strive for improvements within the sector and associated organisations.

I encourage the manufacturing community to support this and other resource efficiency initiatives, not only because they leave a cleaner environment – but also because they are profitable and great for business.

Sir George Buckley
Chairman elect, Smiths Group
Director: Stanley Black & Decker Inc, Pepsico Inc, Archer Daniels Midlands Company, Hitachi Limited
Former Chairman and CEO: 3M Co and Brunswick Corporation



I welcome this report for the important issues it raises around sustainable manufacturing and the range of opportunities it identifies for UK industry to improve its productivity through more efficient use of resources. It fits neatly with my objective of strengthening the manufacturing sector in a forward looking and sustainable manner.

In recent years we have seen increasing volatility in global commodity prices and concerns about security of supply. So a greater focus on efficiency in manufacturing processes looking at use of materials, energy and water, as well as a greater focus on recycling in production and at end of product life will both help firms reduce costs and increase resilience.

The Government is supporting sustainable manufacturing in several ways. The Green Investment Bank, for example, is now operational with £3 billion of finance. It has committed over £700 million already to good projects, alongside private capital with an environmental objective.

There are many companies cited in the report as best practice leaders, and I am very supportive of its efforts to encourage the rest of UK manufacturing to follow their lead.

Working with business, the Government is supporting UK manufacturing by encouraging innovation and technology commercialisation and exports, while improving skills and building UK supply chains. To further facilitate this we have launched the Advanced Manufacturing Supply Chain Initiative (AMSCI) and the Manufacturing Advisory Service (MAS) which are directly helping firms achieve resource efficiency. Additionally, the High Value Manufacturing Catapult Centres and the Technology Strategy Board programmes are helping companies develop innovative production processes and make use of new materials.

These programmes, alongside the Government's industrial strategy, are giving new impetus to manufacturing and providing more clarity about the long term direction in which the Government wants the economy to travel.

I wish every success to the 'next manufacturing revolution'.

The Rt Hon Vince Cable MP
Secretary of State for Business, Innovation and Skills

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Executive summary

Manufacturing generates directly **10% of the UK's GDP** and **employs 2.5 million** people (9% of the employed labour force). Labour productivity improvements in the sector have reduced labour costs since 2001 at a rate of 3% p.a. to £75bn in 2011, a reduction of 1,000,000 jobs.

Conversely, despite spending £340bn annually on goods, materials and services (i.e. **non-labour resources**), these costs have been rising for UK manufacturing sector by 0.4% p.a. since 2004, adjusted for inflation and production volumes.

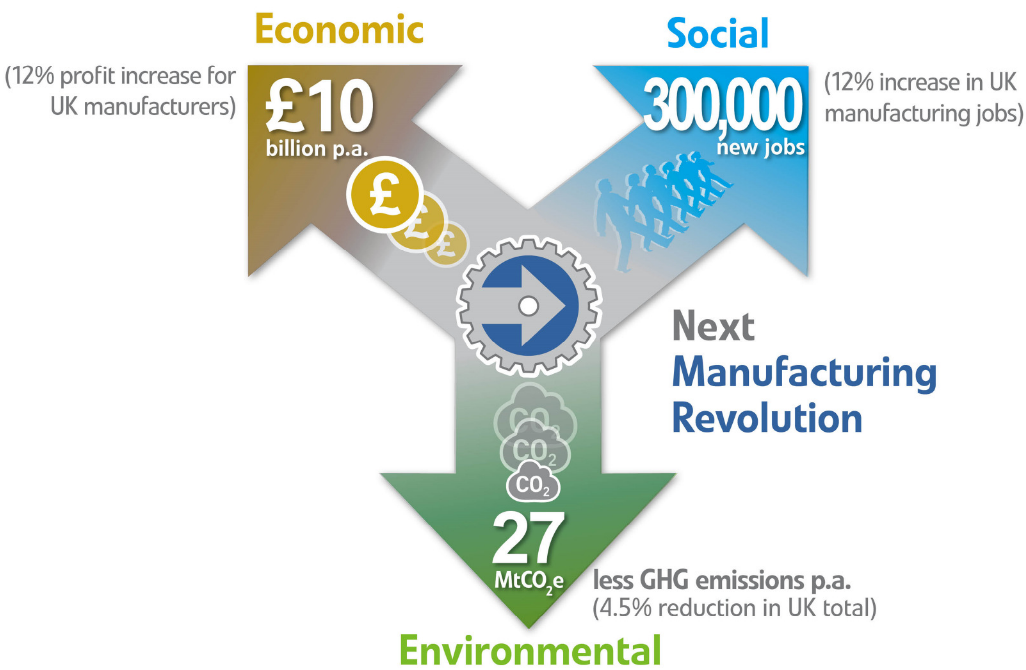
While UK manufacturers have made good progress in some non-labour resource productivity areas, such as recycling and waste to landfill, significant inefficiencies remain. For example:

- Remanufacturing is below 2% for most non-perishable/non-consumable products[1]
- 27% of freight truck journeys are running empty[2]
- Despite the logical benefits of optimising along the supply chain, few UK manufacturers have been engaging in collaborative discussions with their suppliers
- Many companies have achieved 10 to 15% efficiency gains over the last decade, however leading companies have achieved over 50% improvements in the same timeframe.

This study presents opportunities to improve non-labour resource productivity which could enable a **revolution in manufacturing** and are estimated, conservatively, to be worth for the UK:

- **£10 billion p.a.** in additional profits for manufacturers – a 12% increase in average annual profits.
- **314,000 new manufacturing jobs** - a 12% increase in manufacturing employment.
- **27 million tonnes of CO_2 equivalent p.a.** greenhouse gas emissions reduction – 4.5% of the UK's total greenhouse gas emissions in 2010.

Tri-Benefits from the Next Manufacturing Revolution



[1] Details are contained in the Circular Resource Use chapter.
[2] For details and references, refer to the Transport Efficiency chapter.

Additional benefits to the community include indirect employment, improved national resource security (including energy, food and raw materials), reduced pollution, reduced need for landfills, less traffic congestion, reduced load on energy and transport infrastructure (reducing investment and maintenance spend), improved prosperity in the UK agricultural sector, and economic development in developing nations who supply UK manufacturers.

These benefits come from **four types of improvement** (Incremental Improvement, Process & System Improvement, Structural Change and Core Redesign) within the resource productivity fields of circular resource use, energy efficiency, process waste reduction, packaging optimisation, transport efficiency and supply chain collaboration. While some of the identified opportunities are well established, others such as supply chain collaboration are new or are the result of recent technology development or business model innovation.

Potentially, **all manufacturing companies can benefit** from the identified opportunities; the benchmark database developed for this study revealed significant variation in non-labour resource performance between companies within each manufacturing sub-sector. Even pioneering companies leading in one or several areas were found to perform inconsistently across the topics examined.

Eight major barriers to non-resource productivity were found. Four of these apply to most opportunities: senior executive leadership, information, skills and resources. The other four barriers relate to specific types of opportunities and also warrant attention: design, infrastructure, legal constraints and collaboration.

A **programme to address these barriers** has been developed in consultation with a range of multinational manufacturers, relevant government departments, NGOs and experts around the world. It comprises **three streams**:

1. Establishment of an **NMR Community**, for broad engagement and education. This will provide in-depth information, research, tools and interactive information exchange forums. This is designed to build skills and awareness, while inspiring senior executive action. The NMR Community will be openly accessible to all, using the Next Manufacturing Revolution website and the 2degrees platform currently serving over 31,000 members.
2. **Tailored support**, providing assistance for individual organisations. The Next Manufacturing Revolution founding members will work with established manufacturers to identify opportunities for resource productivity improvements, help to construct the investment case for these, and engage senior executives. This will help develop opportunity awareness and provide access to the necessary skills.
3. **Barriers resolution and rollout.** While the above streams begin to address the key barriers, more concerted action is required to eliminate them. This will require collaboration amongst the various stakeholders who can together overcome the barriers to improving non-labour resource productivity. A series of workshops, consulting widely to understand all of the issues and then focussing within small group of senior experts from business, government, NGOs, and academia, will begin in the second half of 2013. The outcome from each will be a plan of action with agreed milestones and commitment to address the barriers.

Implementation of this programme is now underway; collaboration with government, member organisations, other NGOs and established manufacturers will assist to accelerate this programme. The Next Manufacturing Revolution welcomes such organisations seeking to participate.

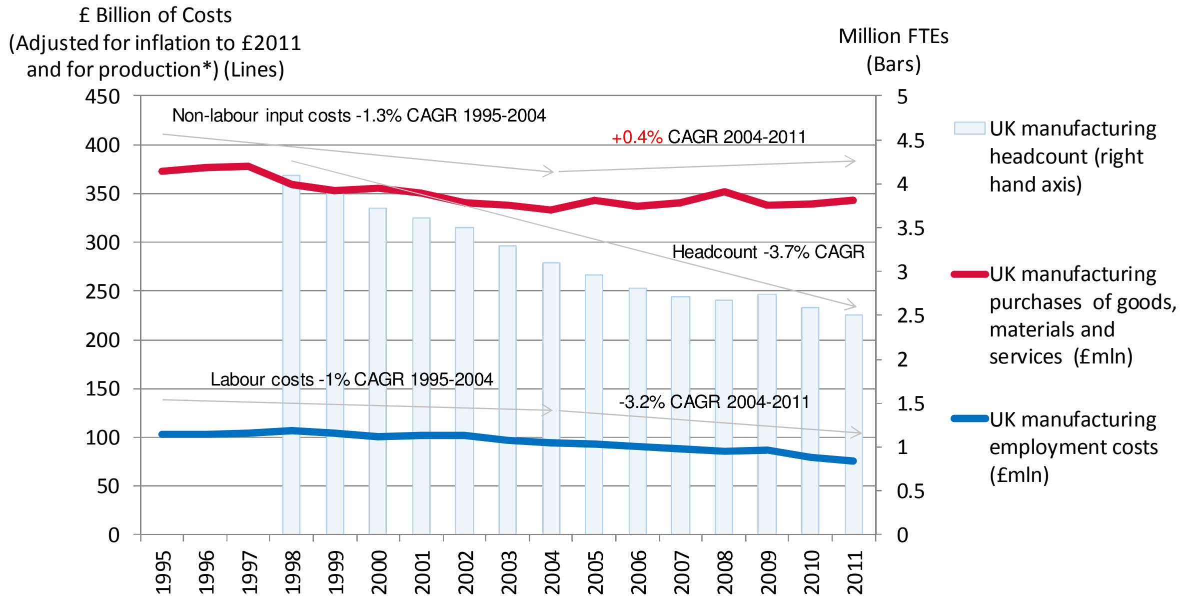
This study is based on input from global experts, multinational corporations, an extensive literature review and a limited sample survey of manufacturers. It has also been peer reviewed by over 40 reviewers.

Chapter 1: Introduction to the Next Manufacturing Revolution

For much of the last decade, the manufacturing sector has focussed on improving labour productivity. This has reduced headcount and labour costs on a like-for-like basis[3] at over 3% per annum over the period (see Figure 1).

By contrast, since 2004, purchases of goods, materials and services[4] have increased at a compound annual rate of 0.4%; in 2011 the UK manufacturing sector's spend on goods, materials and services was 4.5 times its labour spend.

Figure 1: Historical Inputs Spend by the UK Manufacturing Sector Adjusted for Inflation and in £2011[5]



*Adjusted for Index of Production indexed to 1 in 2011.
Sources: Office for National Statistics , Annual Business Survey, C Manufacturing, Release date 15 Nov 2012; Office for National Statistics, Detailed Indices of Production, 2011; World Bank UK inflation data

Appendix 1 presents a sub-sector view of non-labour input costs over this period.

Non-labour input unit costs have increased due to recent structural changes in the global economy:

- Resource constraints including oil and commodities are beginning to emerge.
- Externalities such as carbon, water and waste costs are now being priced into the economy[6].
- Supplier, customer and consumer needs are changing, resulting in uncertainty/volatility of demand and increasing corporate social responsibility expectations.

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[3] Adjusting for inflation and production output by dividing by the Index of Production for the Manufacturing sector, which was indexed at 1 in 2011. Source: Office for National Statistics, Detailed Indices of Production, 2011.

[4] Purchases of goods, materials and services is used as a proxy for inputs of materials and utilities. These have been adjusted for inflation and Index of Production.

[5] All figures have been adjusted for production output by dividing by the Index of Production for the Manufacturing sector, which was indexed at 1 in 2011.

[6] Through taxes/charges (e.g. landfill tax), trading schemes (such as the European Emissions Trading Scheme), legislation (e.g. anti-pollution requirements) and societal expectations (e.g. expecting companies not to dump toxic wastes).

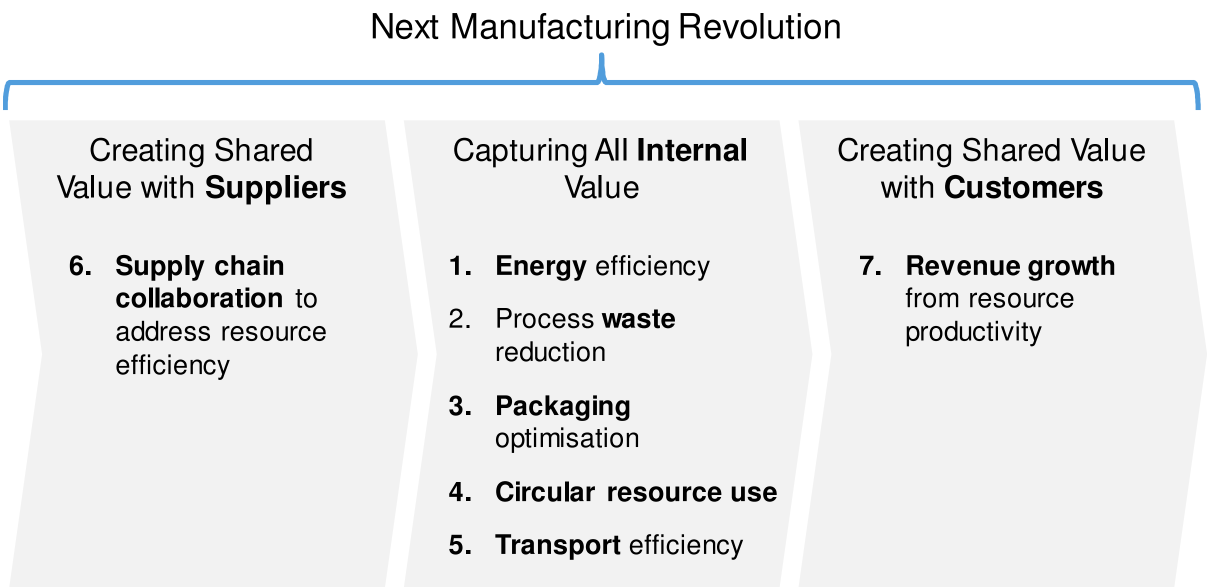
Given the success of the manufacturing sector at improving labour productivity, the non-labour resource reductions achieved by pioneering companies and the increasing non-labour input costs now impacting on business, we see significant profit improvement opportunities in the area of **non-labour resource productivity** (i.e. doing more with less). Reducing resource use is not only profitable but also has environmental benefits and creates jobs, unlike labour productivity which cut 1.5 million jobs from 1998 to 2011[7].

The business environment after the financial crisis has increased corporate openness to these new opportunities. Cash is precious; executives are looking to reduce costs and grow their businesses with minimal capex. Collaboration with suppliers and customers is increasing as companies recognise the importance of relationships and benefits of joint problem solving[8]. New technologies and business models are emerging. Local production is increasing to mitigate supply risks and improve responsiveness.

These recent shifts present opportunities for the manufacturing sector that together are significant enough to amount to the next manufacturing revolution[9] – as this study will demonstrate.

Specifically, seven areas of substantial value creation opportunity have been identified for the manufacturing sector and are examined in this Next Manufacturing Revolution study (see Figure 2). All offer greater profits while lowering a manufacturer's environmental footprint and can, either directly or through improving the cost base of UK manufacturing, safeguard and grow British manufacturing employment.

Figure 2: Areas of Significant Value Opportunity for Manufacturers – The Drivers of the Next Manufacturing Revolution



[7] On a like-for-like basis, adjusting for changes in production output.
[8] There is increasing recognition that optimising across multiple steps in a supply chain brings benefits beyond optimising for a single step.
[9] The validity of using the term 'revolution' is supported in Appendix 2, where the implications of resource productivity for manufacturing are compared with what occurs in scientific revolutions as characterised by Thomas Kuhn.

While many of these topics are familiar to manufacturers, they have rarely been pursued to their full potential. In part, this is because they have never been explicitly quantified[10] and aggregated to secure the senior management attention, resources and expertise that they warrant, but also because they face a range of barriers to adoption. Addressing these resource efficiency topics together, therefore, builds a more compelling case for change and can create a coherent roadmap to increased profitability.

When ‘revolutions’ occur, the economic benefits to those companies and countries at the forefront of the change are disproportionate: profits increase, new industry leaders emerge with strong competitive positions that can last for decades and host countries’ jobs, economies and exports all benefit. This next manufacturing revolution will also bring societal and environmental benefits which are a consequence of addressing today’s opportunities; the ‘green economy’ is an integral part of the next manufacturing revolution that will also, for some sub-sectors, bridge the cost difference between producing onshore and outsourcing to other nations with lower labour costs.

The financial crisis and the new business parameters therefore create the opportunity for the reinvention of existing firms and the growth of new ones. A number of companies around the world have begun to seize these opportunities – creating first mover advantage for them[11].

Lavery Pennell, 2degrees and the University of Cambridge Institute for Manufacturing believe it is in everyone’s best interest to accelerate the transition. To this end we are pooling our skills, experience and resources to turn this vision into reality. Our backgrounds assisting leading companies to further extend their advantage provide us with unique insights into the transition.

Our initial focus is on the UK manufacturing sector[12] as a test case for the Next Manufacturing Revolution; the findings are applicable to most countries[13]. The UK is also well placed to lead the next revolution, with its strong heritage of innovation, leadership of previous manufacturing revolutions and need to revitalise its economy and create manufacturing jobs.

This report gathers together evidence to show the dimensions and magnitude of the value that is available and already being captured by early movers and reviews the barriers to rapid adoption. An ongoing programme of activities, outlined at the end of this document, will address these barriers.

This study is based on discussions with leading experts and companies, the experience of the authors over many projects assisting companies with their non-labour resource productivity, a literature review, research including a survey of UK manufacturers (an overview of which is presented in Appendix 3), an examination of the historical performance of UK manufacturing sub-sectors and the creation of a benchmark database of global best practices in the seven fields of opportunity for each of the manufacturing sub-sectors.

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[10] Resource inefficiency is often hidden. For example, the cost of process waste is often assumed to be the cost of disposing material to landfill, whereas it actually includes the embodied raw materials, processing and labour.

[11] For examples, refer to the ‘Case Studies’ tab on www.nextmanufacturingrevolution.org.

[12] ‘Manufacturing’ for the purposes of this study corresponds with Standard Industrial Classification (2007) Section C: Manufacturing, with the exception of Division 19: Manufacture of coke and refined petroleum products. That is, it includes Fast Moving Consumer Goods, chemical production, petrochemicals, engineered products (eg automotive and aerospace), industrial companies, and other sub-segments conventionally considered to be manufacturing. Excluded are the waste, construction and extractive industries.

[13] Peer reviewers from around the world have acknowledged the same manufacturing circumstances and challenges as well as the potential of resource productivity.

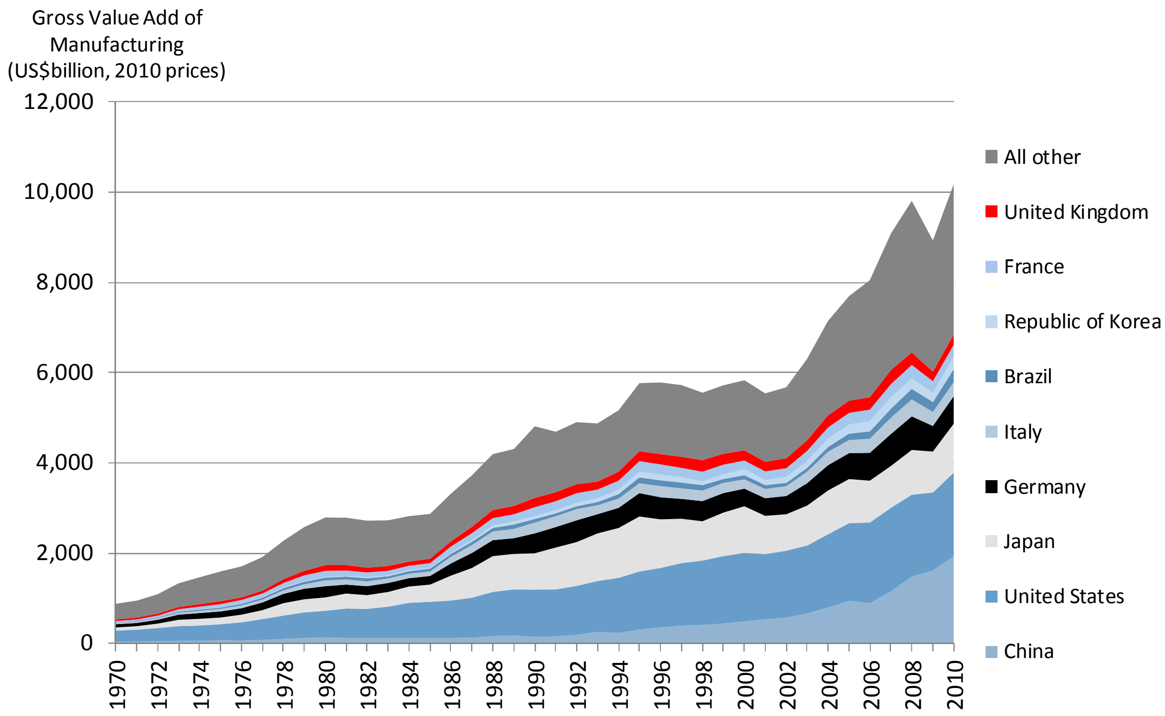
This work draws upon a strong foundation with many companies and researchers working on these topics for decades before the greater public recognition which is now emerging. Industry pioneers have been busy reducing costs and environmental impacts, often following a lonely path, with companies such as such as ICI re-using waste chemicals, Toyota Europe reducing energy consumption, GSK recycling PET packaging and Unilever reducing water use leading the way (along with many others). Leading researchers have been offering visions often far ahead of their time, for example Walter Stahel inventing the concept of cradle-to-cradle material cycles in the 1970’s, or Amory & Hunter Lovins, together with Paul Hawken introducing concepts of Factor 10 Engineering and natural capitalism. In resource productivity the work of the early industrial ecologists of Yale and Princeton in the USA and Gunter Pauli in Europe have shown what is possible and how to change our understanding of the industrial system to find win-win improvements across economic, social and environmental performance.

Chapter 2: The Importance of Manufacturing to the UK Economy

The gross value add of the manufacturing sector[14] in the UK in 2011 was £154 billion[15], directly representing 10% of the UK's GDP[16]. Purchases of goods, materials and services by the manufacturing sector were £340 billion in 2011, contributing further to the UK's GDP [17].

Contrary to popular opinion, UK manufacturing has not continuously declined over the last few decades. In 2010, the UK was the ninth largest manufacturing nation (see Figure 3).

Figure 3: Manufacturing Gross Value Add (i.e. contribution to GDP) by Country



Source: United Nations Statistics Division, National Accounts Estimates of Main Aggregates

The UK manufacturing sector has continued to grow in real value in each of the last four decades, maintaining between 3.3% and 4.5% of the world's manufacturing gross value add until 2007 (see Figure 4).

Since 2007, however, the value of the UK's manufacturing gross value add dropped by £50 billion, which caused UK contribution to world manufacturing GVA to drop to 2.3% in 2010 - a 32% drop from the 3.4% contribution in 2007 (see Figure 4). While this drop can be explained by the financial crisis impacting heavily on UK manufacturing compared with emerging nations where production growth only slowed, it is nevertheless a worrying development.

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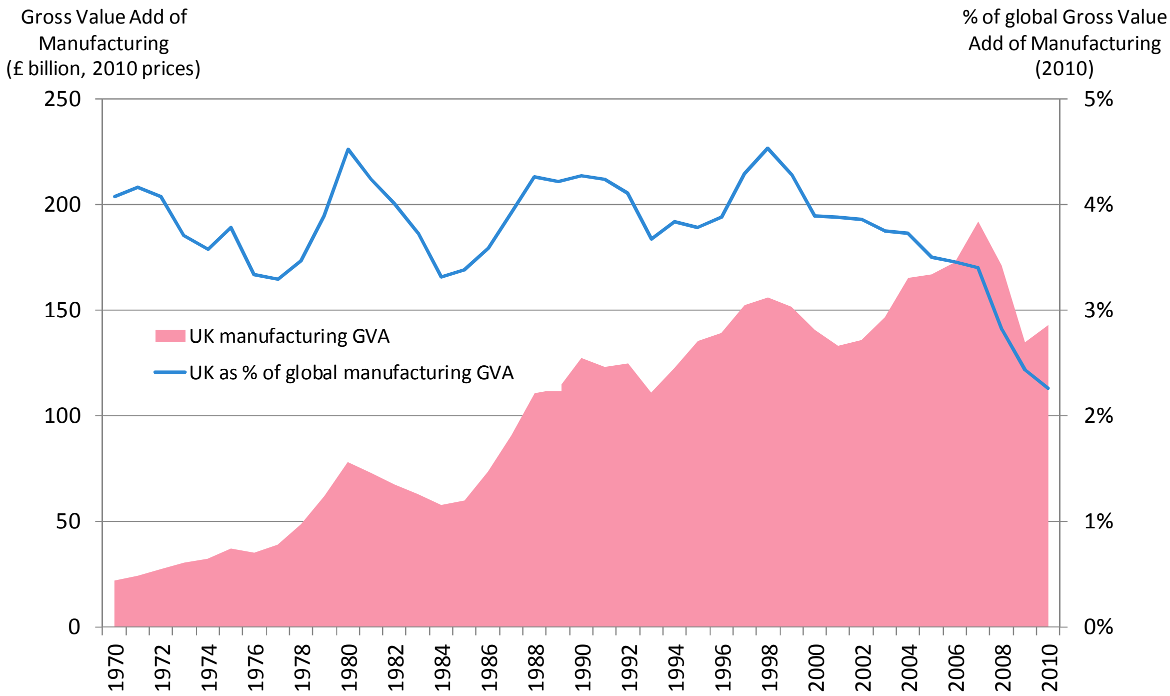
[14] Defined as SIC (2007) Section C: Manufacturing.
[15] Office for National Statistics, Annual Business Survey, Section C Manufacturing, release date 15 November 2012.
[16] Note that Gross Value Add is used to calculate the contribution of the manufacturing sector to Gross Domestic Product because it avoids double-counting of input materials, goods and services.
[17] Office for National Statistics, Annual Business Survey, Section C Manufacturing, release date 15 November 2012.

Figure 4: UK Manufacturing Gross Value Add and Percentage of Global Manufacturing GVA



Source: United Nations Statistics Division, National Accounts Estimates of Main Aggregates

With £235 billion in exports, manufacturing comprised 55% of UK exports in 2010[18]. This sector therefore is a critical contributor to the UK's balance of payments.

Around 2.5 million people were employed directly by the UK manufacturing sector in 2011, which represented 9% of the UK's employed labour force[19]. Indirect jobs, from retail stores near plants to service suppliers, multiply this.

Beyond these economic and societal impacts, manufacturing also accounts for a significant proportion of UK resource consumption, as well as pollution. Greenhouse gas emissions related to UK manufacturing were estimated to be 113MtCO_2e in 2010[20], 19% of the nation's 2010 total of 590MtCO_2e[21].

[18] Office for National Statistics, UK Trade in Goods Analysed in Terms of Industries, Q2 2011; Office for National Statistics, Monthly Review of External Trade Statistics, July 2011.
[19] Office for National Statistics, Annual Business Survey, Section C Manufacturing, release date 15 November 2012; Office for National Statistics, Labour Market Statistics, September 2012 release.
[20] Includes the greenhouse gas emissions from fuel used, electricity consumed and industrial processes, as well as 25% of road freight transport. Refer to the Transport Efficiency chapter for a detailed explanation of the road freight transport figure. Sources: DECC, 2011 UK Greenhouse Gas Emissions, Provisional Figures And 2010 UK Greenhouse Gas Emissions, Final Figures By Fuel Type And End-User, Statistical release, 29 Mar 2012, Table 7; DECC 270-ecuk-industrial-2010, Table 4.6c(i), http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx; Defra, 2012 greenhouse gas conversion factors for company reporting, May 2012, https://www.gov.uk/government/publications/2012-greenhouse-gas-conversion-factors-for-company-reporting; Transport efficiency chapter.
[21] DECC, 2011 UK Greenhouse Gas Emissions, Provisional Figures and 2010 UK Greenhouse Gas Emissions, Final Figures By Fuel Type And End-User, Statistical release, 29 Mar 2012, Table 7.

Chapter 3: Energy Efficiency

This chapter discusses energy efficiency related to fuel and electricity use in manufacturing. Transport efficiency is covered in a separate chapter.

Chapter Summary

In 2011, the total UK energy usage in the manufacturing sector in fuels and electricity was 26.7 million tonnes of oil equivalent (toe)[22], which cost £9.4 bln.

For the past two decades, the energy intensity of each manufacturing sub-sector has been gradually decreasing due to a number of background reasons including improved equipment design, better management practices, improved production processes and offshoring. Since 2002, with the rapid rise in energy prices, many companies have also actively increased their energy efficiency activities.

To date, companies have used a number of energy efficiency improvement approaches, ranging from incremental behavioural changes and putting energy management processes in place, through to more fundamental structural and core redesign changes to their businesses and products.

Best practice companies in most manufacturing sub-sectors are reducing their energy intensity at 4% p.a. compound or better above the background improvement rate. Moving the UK manufacturing sector to these higher improvement rates provides a gross opportunity of **£1.9 billion p.a.** in energy savings, over and above ongoing efforts, as well as greenhouse gas emissions savings of **19MtCO_2e p.a.**

Energy efficiency activities also create skilled jobs at the rate of 7.7 jobs per £1million spend p.a. Implementing the savings identified would create 3,500 new full time jobs.

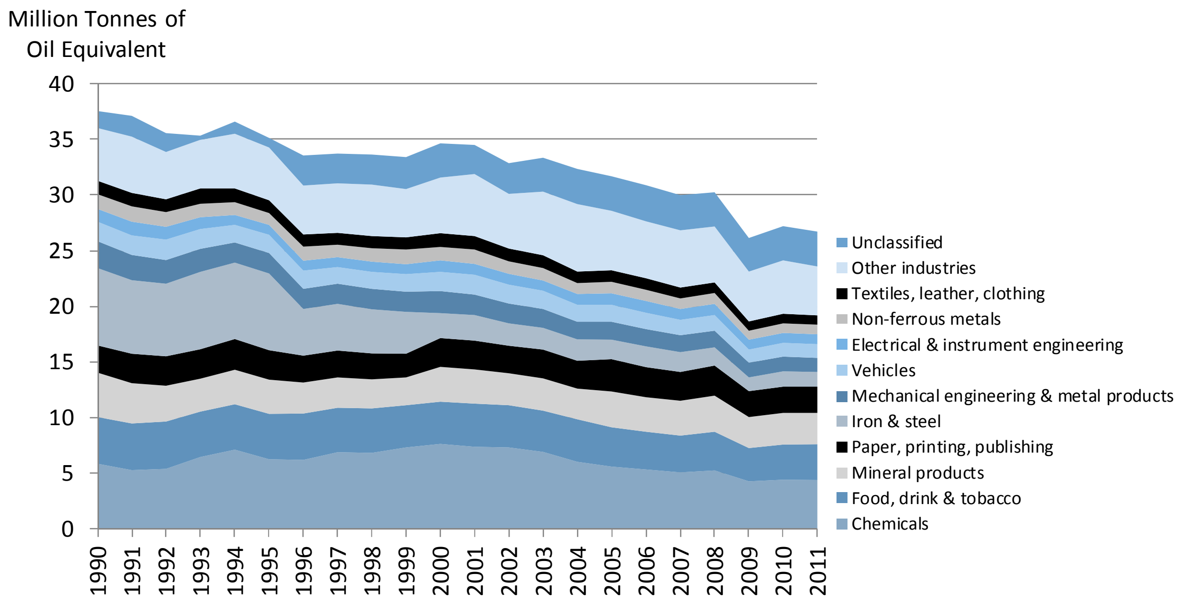
Four key barriers currently prevent the UK from reaching its energy efficiency potential: senior executive leadership; information; resource constraints, and; application of an appropriate skill mix.

[22] This does not include freight transport fuel use, which is covered in the Transport Efficiency chapter.

Energy Use and Intensity Trends

The UK manufacturing sector spent £9.4 billion on energy in 2010[23]. Absolute stationary energy usage in the sector was 26.7 million tonnes of oil equivalent in 2011[24] and has declined considerably in recent decades (see Figure 5).

Figure 5: Historical UK Energy Consumption by Manufacturing Sector



Source: Energy Consumption UK 2010, Department of Energy and Climate Change

There are multiple reasons for this reduction including changes in production mix and volume as the UK economy has shifted, offshoring, altered production volumes due to changing demand, fuel mix (although this has been minor) and improvements in energy efficiency.

To examine efficiency over time on a like-for-like basis, a comparison of energy intensity has been used, defined as the energy used per unit of output, normalising for volumetric and offshoring changes. For this analysis, energy intensity has been calculated by dividing the energy used per sub-sector in each year by the corresponding Index of Production for that year. The Index of Production measures the volume of production at base year prices for manufacturing sub-sectors[25]. This approach is consistent with that used by the UK's Department of Energy and Climate Change.

The change in energy intensity over time provides insights into the rate of adoption of energy efficiency opportunities within sub-sectors[26].

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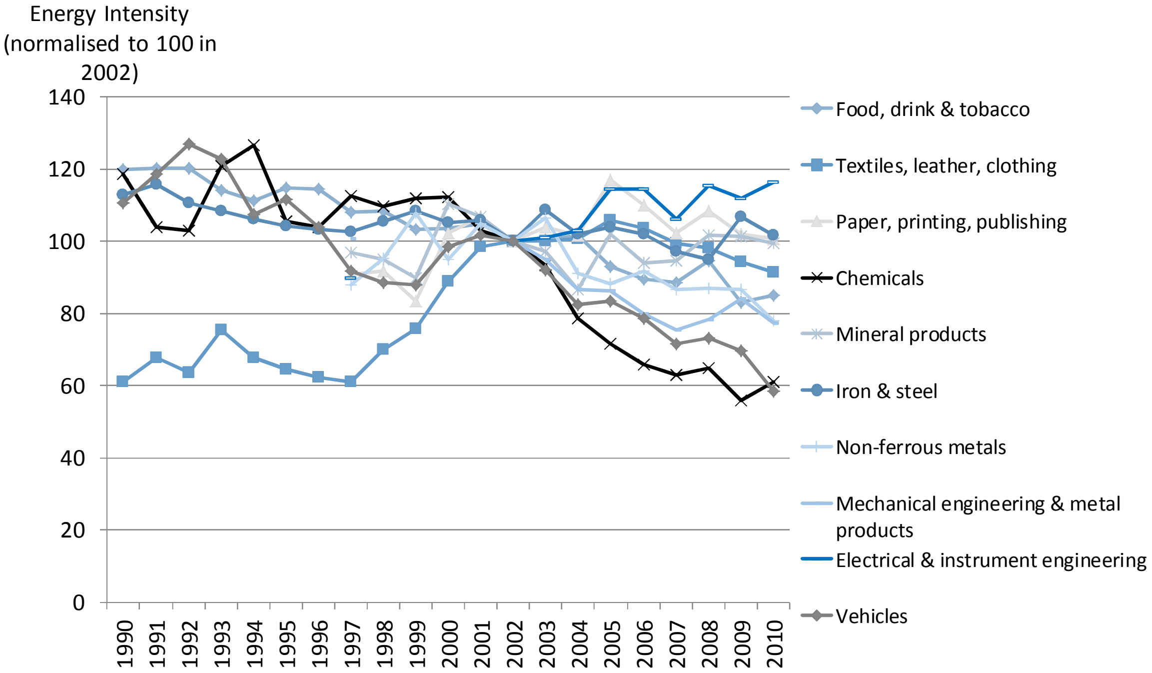
[23] Sources: DECC 270-ecuk-industrial-2010, Table 4.6c(i), http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx; DECC Quarterly Energy Prices September 2011. Excludes manufacture of coke and refined petroleum products.
[24] Department of Energy and Climate Change, Energy Consumption in the United Kingdom, DECC, 2012. http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx
[25] Further information on the UK's Index of Production can be found at the Office of National Statistics website http://www.ons.gov.uk/ons/guide-method/method-quality/specific/economy/index-of-production/index.html
[26] For the methodology used to calculate energy intensity improvements per sub-sector, refer to Appendix 5.

Figure 6 compares the energy intensity of manufacturing sub-sectors on this basis from 1990 (or 1997 if earlier data was unavailable) to 2010, normalised to 100 in 2002 to enable visual comparison.

Figure 6: UK Energy Intensity by Manufacturing Sub-Sector



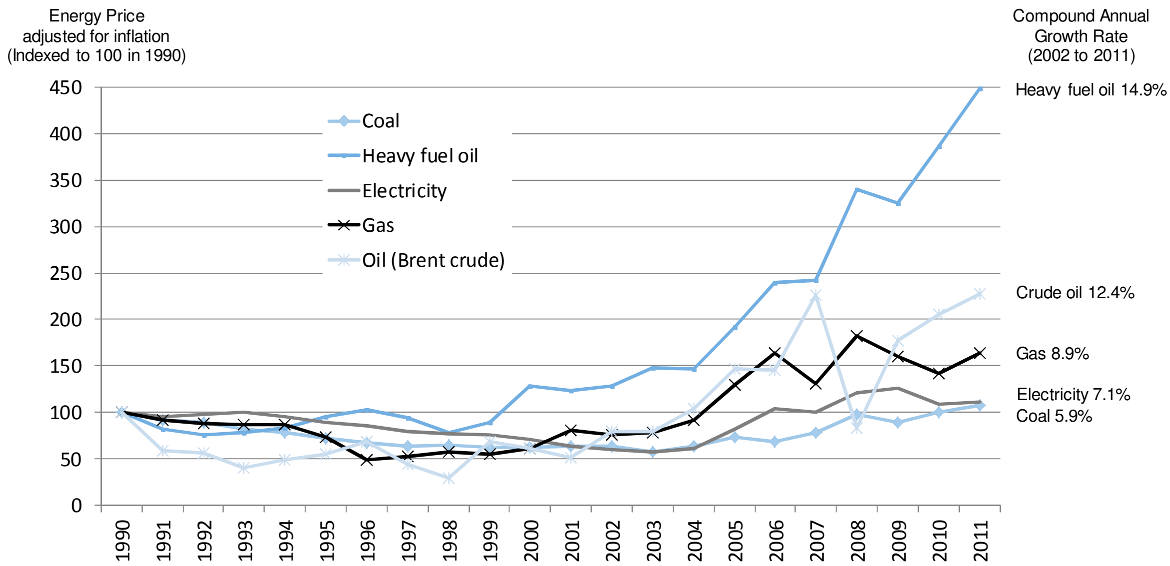
Sources: Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011

There is a clear distinction between the rate of energy intensity improvement before and after 2002 for most sub-sectors. Pre-2002, energy intensity declined at a modest rate for most sub-sectors, indicating the existence of a 'background' energy efficiency effect for each sub-sector. This background effect includes advances in technologies, equipment, processes, management skills, and business models[27].

The year 2002 corresponds with the beginning of a rapid increase in energy prices (see Figure 7). After this date, rates of energy intensity improvement increased, consistent with the observation that when energy prices rise, companies increase their energy efficiency efforts to reduce the impact of input price increases on their overall profitability.

[27] The substantial increase in energy intensity which occurred in the textiles, leather and clothing sub-sector from 1997 to 2002 is considered to be the result of the substantial off-shoring of clothing production which occurred in this period which substantially changed the mix of production in the UK.

Figure 7: Energy Prices over Time

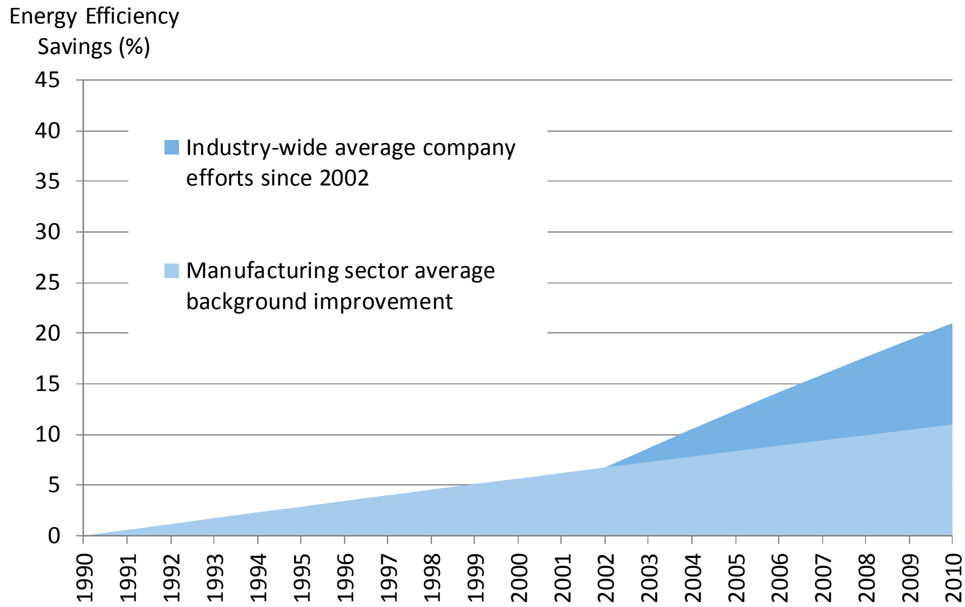


Notes: All data in constant dollars. Does not include Carbon Levies
Sources: DECC for energy prices except crude oil, http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/prices/prices.aspx#industrial; Office of National Statistics for CPI; Wikiposit for crude oil prices

Government stimulus to encourage energy efficiency within companies has also increased since the early 2000's, including the Carbon Trust which was founded in 2001, the European Union Emissions Trading Scheme which commenced in 2005 and the CRC Energy Efficiency Scheme (formerly the Carbon Reduction Commitment) which began in 2007.

Assuming that the rate of background efficiency improvements remained unchanged post-2002, we are able to calculate the impact of corporate energy efficiency initiatives over and above the background improvement rates. These are shown averaged for the whole manufacturing sector in Figure 8.

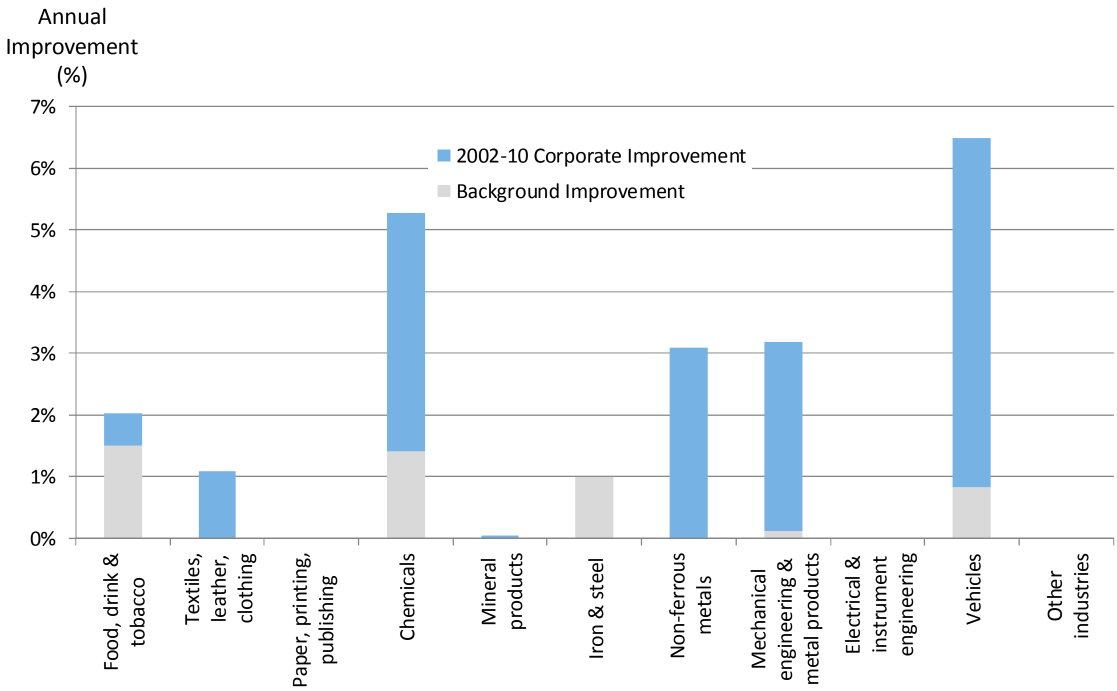
Figure 8: Background and Company Energy Efficiency Savings Averaged over the Entire Manufacturing Sector



Sources: Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011

Figure 9 presents the background and company-driven energy intensity improvements for individual manufacturing sub-sectors. Note that where energy intensity increased pre-2002 or 2002-10, the background energy efficiency impact has been taken as zero recognising that no manufacturing sector or its suppliers is likely to be actively working to increase energy costs or inefficiency and therefore these increases are most likely the result of exogenous factors.

Figure 9: UK Annual Energy Intensity Improvement by Manufacturing Sub-Sector



Sources: Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011

The differing rates of improvement in energy efficiency between sub-sectors can be attributed to a range of factors, including:

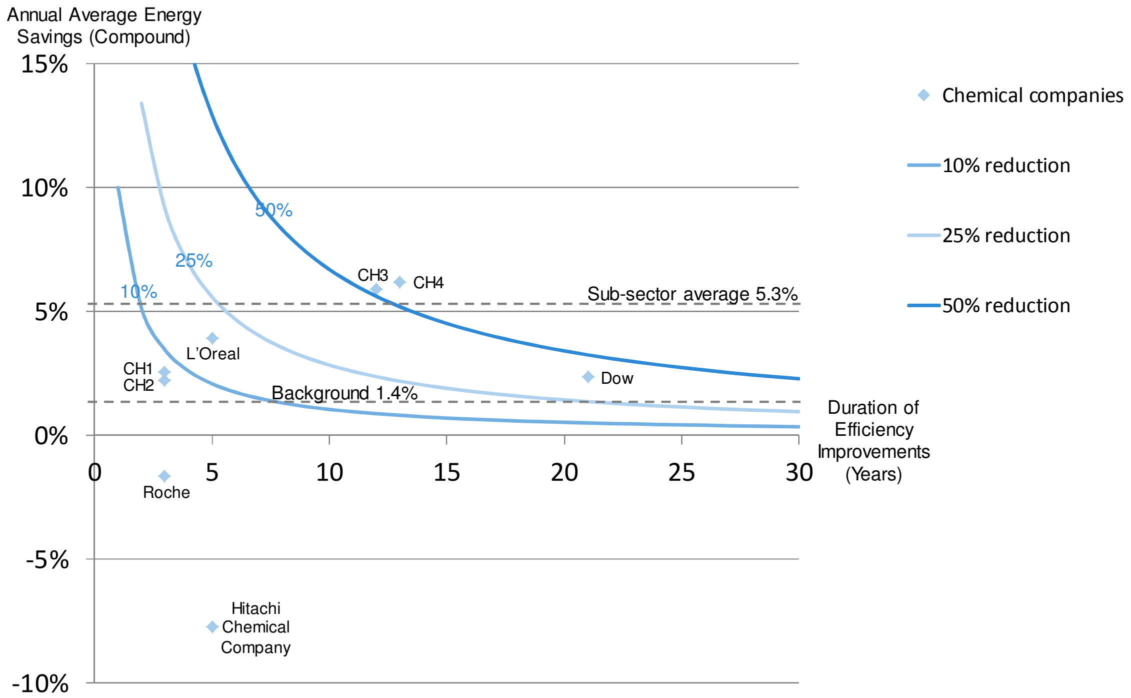
- Proportion of energy in a sub-sector's cost base. If energy is only a small fraction of costs, then it is likely not to receive substantial attention until energy prices are high and/or the economic cycle forces scrutiny of all costs.
- Historical efficiency improvements. The steel industry, for example, underwent wholesale upgrading in the decades preceding the 1990's, adopting more efficient practices and plants, given their high energy use. This locked in the more efficient equipment/technology for long periods.
- Competitive dynamics. In some sub-sectors, market leaders have reduced their costs and improved their green image/brand equity through reducing energy use – enabling them to increase their market share. Competitors are quick to follow to maintain their sales volumes and this can lead to rapid improvement in energy efficiency (and other resource productivity areas) for a whole sub-sector.

Company Energy Intensity Performance

To identify the full potential for each sub-sector, the performances of individual companies were examined in order to identify best practices. Company data was gathered in the Next Manufacturing Revolution survey and an extensive literature review. Figure 10 and Figure 11 present the performance of a range of companies in two example manufacturing sub-sectors: chemicals and food, beverage and tobacco. The x-axis shows the number of years since the company began its energy efficiency improvements and the y-axis shows the annual average compound improvement rate in energy consumption per unit of production. Isoclines show the combinations of time and rate of improvement that achieve a 10%, 25% and 50% overall absolute energy intensity saving. Background and sub-sector average improvement rates for the UK are also plotted for comparison.

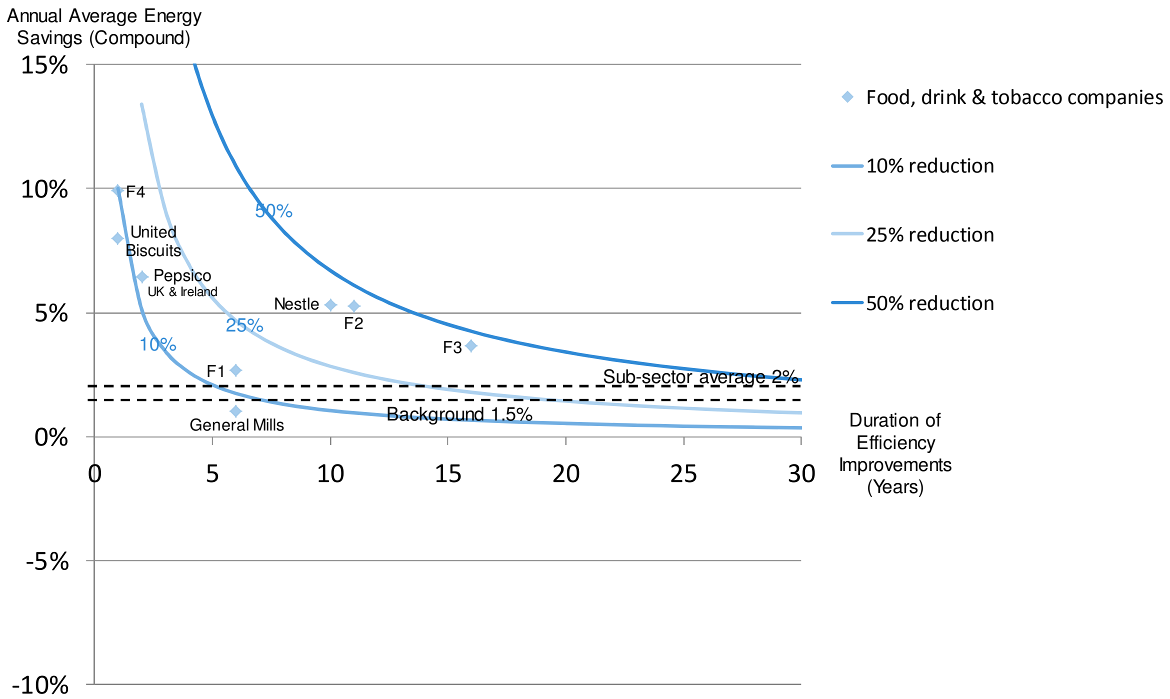
Similar graphs for other manufacturing sub-sectors are presented in Appendix 4.

Figure 10: Chemical Companies' Energy Intensity Improvements



Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 11: Food, Beverage and Tobacco Companies' Energy Intensity Improvements



Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Overlaying a five-year threshold for energy efficiency improvement rates to be part of a sustainable programme[28] enables a segmented view of companies (see Figure 12 and Figure 13). Four segments of companies are apparent, based on annual energy intensity improvement and duration of improvement:

1. **Leaders** – those companies who have exceeded sub-sector average energy intensity improvements for over five years. Many of these have achieved substantial reductions.

2. **Stars** – companies who have achieved greater than industry average energy intensity improvements, but for a period of less than five years. These are either companies beginning their energy efficiency journey ('Rising Stars') or those who saw a brief period of improvement which may be brief ('Shooting Stars').

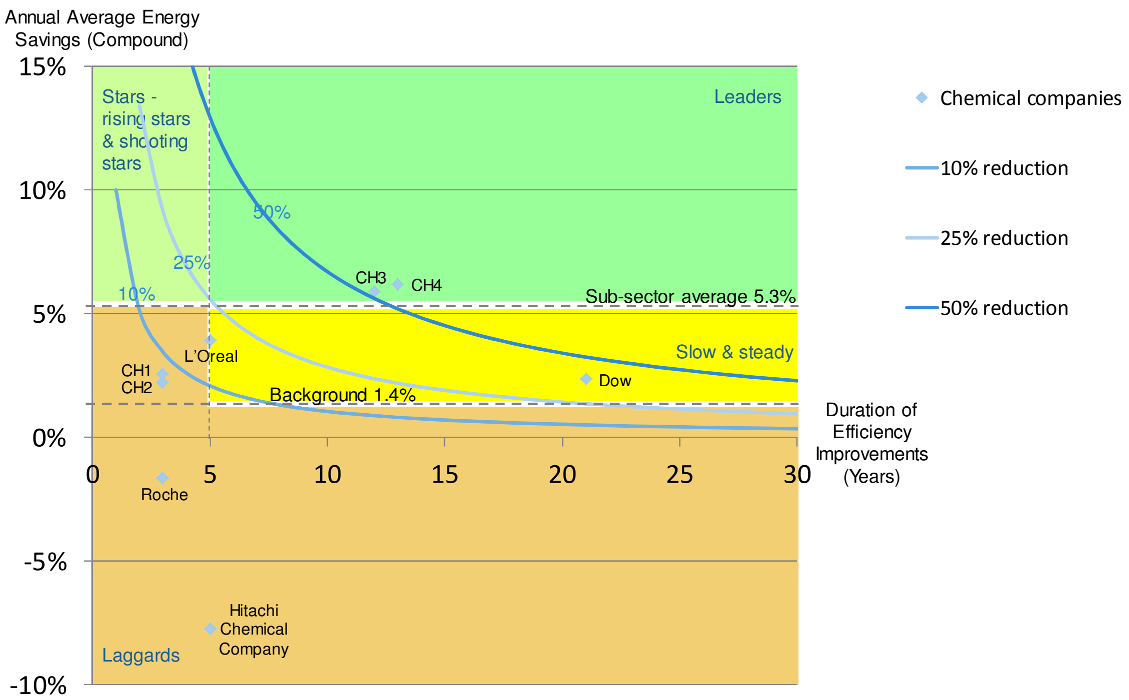
3. **Slow and steady** – companies achieving a smaller than sub-sector average energy intensity improvement but greater than background improvement for more than five years.

4. **Laggards** – those achieving less than sub-sector average improvements in less than five years or performing worse than background energy intensity improvement.

A number of companies stand out as exceptional in their energy intensity reductions – both for their annual rates of energy intensity reduction and the period over which they have sustained these improvements, resulting in substantial energy intensity reductions.

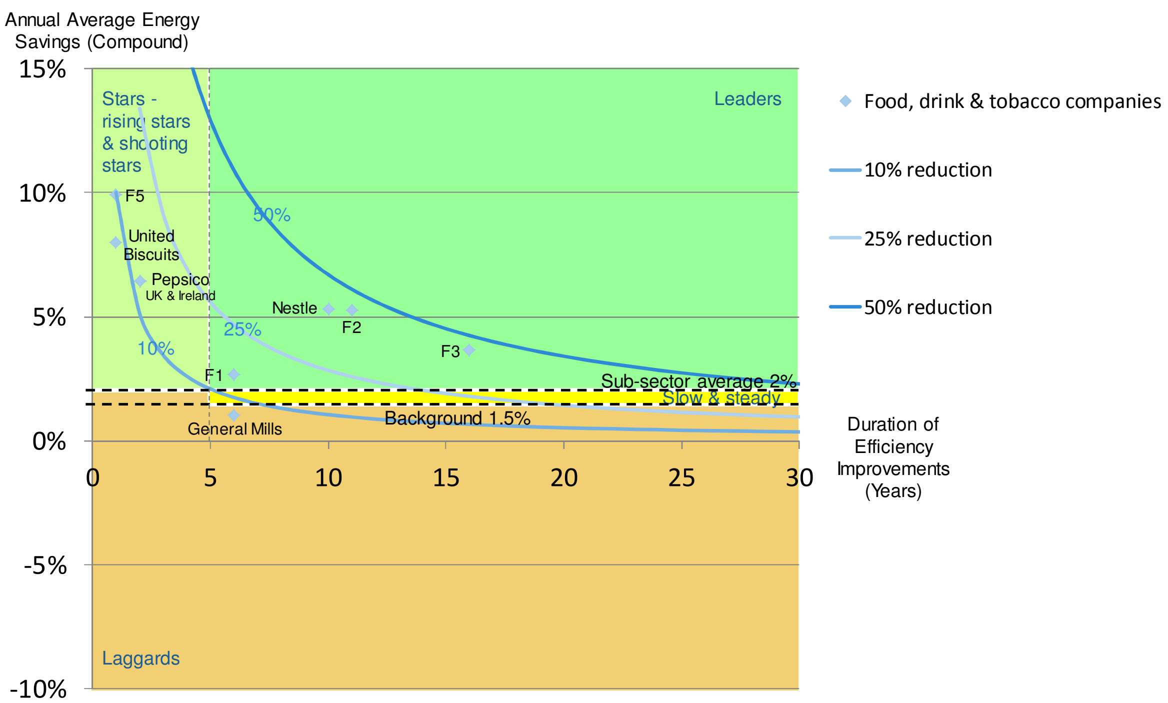
[28] To identify sustainable levels of energy efficiency improvement, a threshold of five years was adopted. Five years was chosen because it can take a year to design an energy efficiency program and several years to implement and capture quick wins, beyond which a company begins to drive more embedded savings requiring good energy management systems and executive commitment.

Figure 12: Chemical Companies' Energy Intensity Improvements with Overlaid Segments



Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 13: Food, Beverage and Tobacco Companies' Energy Intensity Improvements with Overlaid Segments

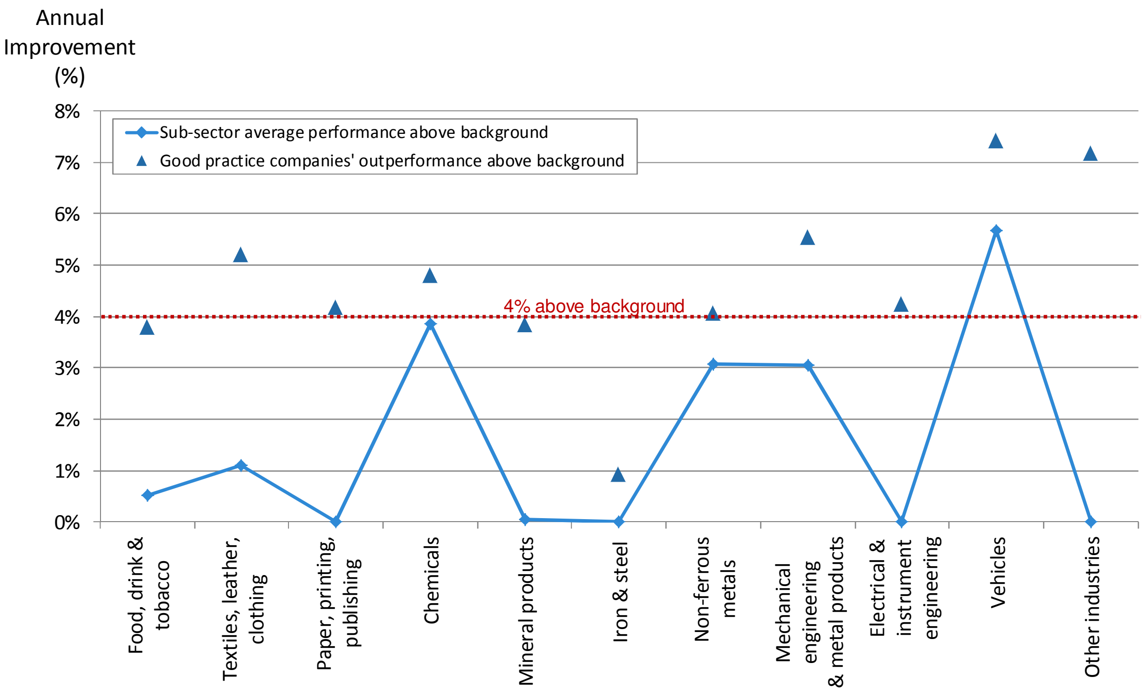


Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Best Practice in Energy Intensity Reduction

Best practice company levels of energy intensity improvement are summarised in Figure 14, which presents the 2002 to 2010 energy intensity improvement (above background effects) for each sub-sector as well as good practice companies in each sub-sector[29].

Figure 14: 2002 to 2010 Energy Intensity Change by Sub-Sector and Good Practice Companies



Sources: Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011; Next Manufacturing Revolution Survey responses; Literature review

As can be seen from Figure 14, with the exception of iron and steel, a 4% per year improvement in energy intensity above background has proven achievable in all sub-sectors[30]. Notably, the UK chemicals and vehicles sub-sectors have, on average, reduced energy intensity by 4% or greater every year from 2002 to 2010.

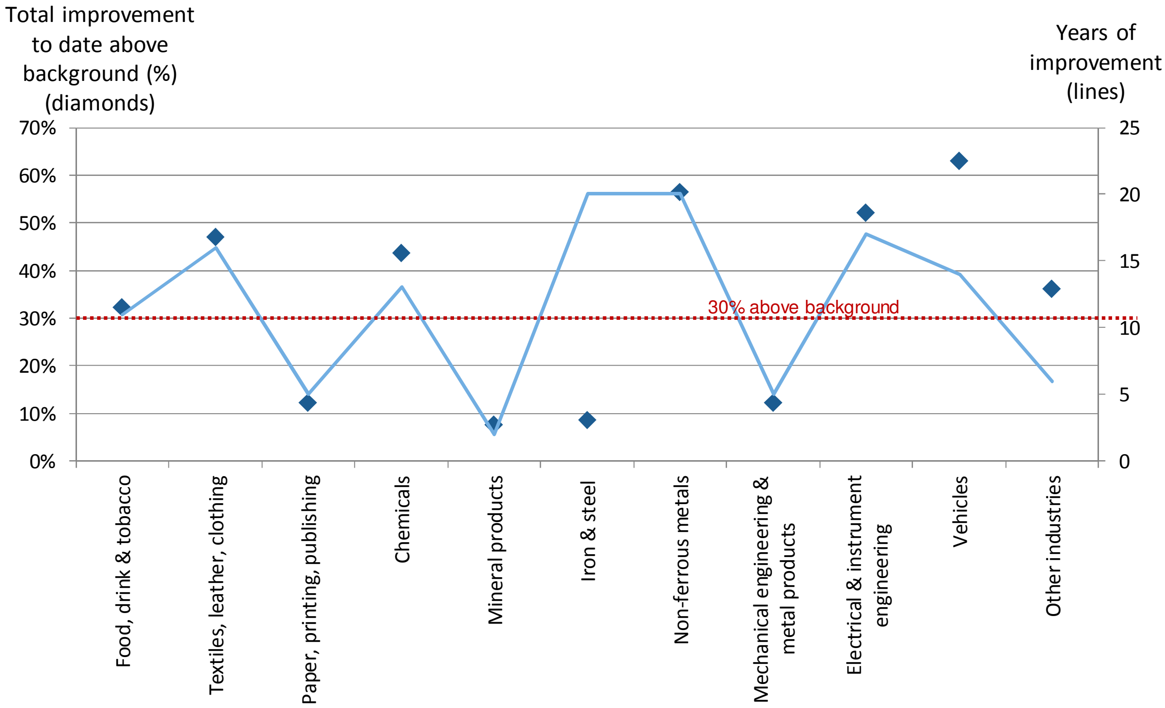
The difference between sub-sector average performance (above background) and best practice can be considered as the energy intensity improvement potential for the sub-sector. However, there may be a limit on how long high rates of improvement can be sustained - beyond which improvements are difficult and impractically expensive. Existing good practice suggests that a 30% total improvement beyond background is achievable for most sub-sectors and has been substantially bettered in a number of sectors (see Figure 15). Most of the sub-sectors below 30% are where only a

[29] All of the good practice companies shown in Figure 14 demonstrated these levels of annual improvement for over five years, except for the paper, printing and publishing sub-sector, for which good practice company data was only available for three years, and the minerals, non-ferrous metals and mechanical engineering & metal products sub-sectors for which data was only available for two years.

[30] The iron and steel sub-sector has seen increases in energy intensity in recent years by many companies around the world. However, there are a number of process innovations which have been proven which can be adopted to reduce energy use, such as the Arvedi endless strip production process and electric arc furnace heat recovery (see, for example, Allwood, J.M., Cullen, J.M. Sustainable Materials - with Both Eyes Open: Future Buildings, Vehicles, Products and Equipment - Made Efficiently and Made with Less New Material, UIT Cambridge, 2011, pp. 126, 132.)

few years of data are available for the good practice companies and so may, as ‘Rising Stars’, go on to achieve substantial savings.

Figure 15: Total Energy Intensity Performance Improvement of Best Practice Companies above Background



Sources: Next Manufacturing Revolution Survey responses; Literature review

How Good Practice Companies Reduced their Energy Intensity

Companies achieving substantial energy intensity improvements have typically addressed all of four types of energy saving opportunities, each differing in ease and investment requirement:

1. **Incremental**. These opportunities involve mostly behaviour and cultural change, such as monitoring energy usage, identifying and rectifying anomalous behaviour, addressing wasted energy and encouraging staff to reduce energy use. Incremental opportunities are often referred to as ’quick wins’ because they can be implemented more quickly, do not involve capital expenditure and can create tangible savings.

2. **Processes and Systems**. Energy improvements that involve changes in processes fall into this category, such as establishing an energy management program/team, changing operating procedures to reduce energy use, improving maintenance regimes, and setting up energy use reporting systems. Many of these savings are inexpensive in capital terms, but result in substantial savings.

3. **Structural Change**. Where new equipment or production process redesign is involved, this is structural change for a company, often involving capex and usually occurring as part of scheduled maintenance or replacement. Typical areas of opportunity in the manufacturing sector include installing more efficient process equipment (e.g. pumps, motors, boilers),

efficient lighting, improving HVAC in warehouses, and redesigning production process to reduce energy use such as through more optimal heat cascading.

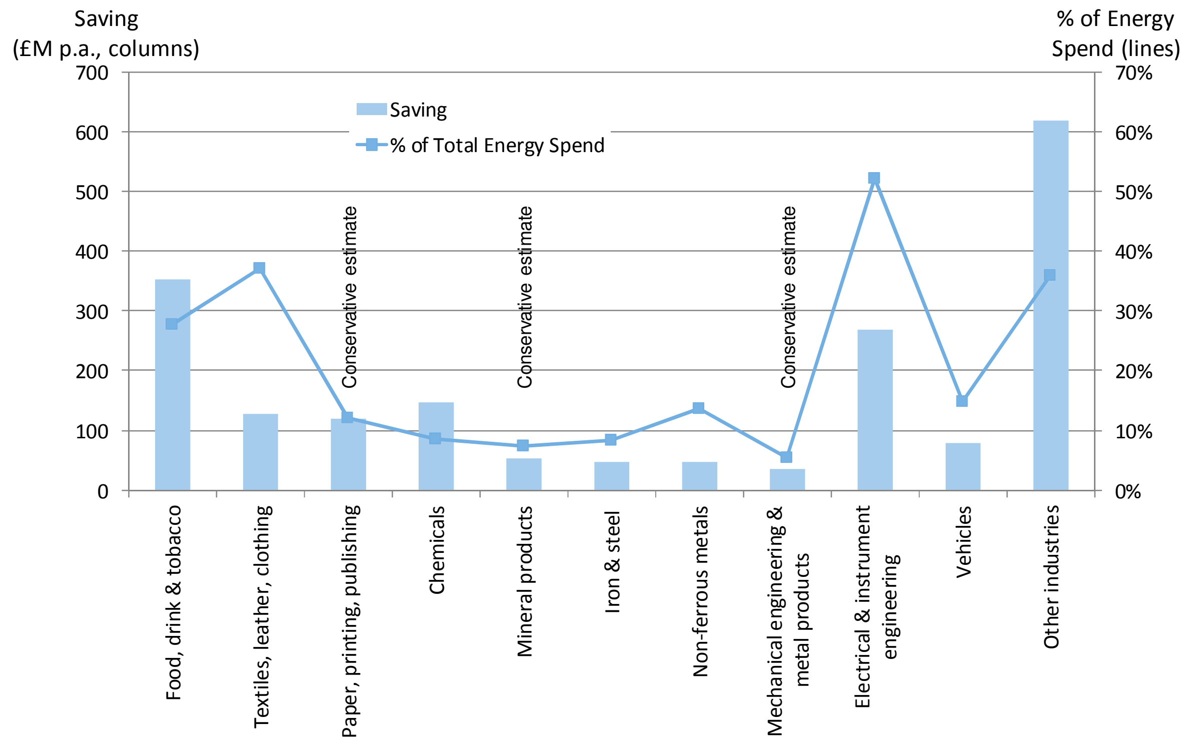
4. **Core Redesign**. Altering the core of a business, such as redesigning products to reduce energy requirements or changing a company's business model (e.g. leasing versus selling, service delivery versus product) are core changes which can lead to the greatest energy savings. For example, Xerox leases rather than sells photocopiers, enabling them to maintain the machines, extend their working lives, recycle components, and reduce manufacturing energy use – while enabling customers to avoid the hefty up-front purchase price of a new machine. The cost and payback periods of core changes can be longer than other energy saving opportunities, and such ideas can be slow and difficult to implement in a company resistant to change.

Examples for a range of manufacturing sub-sectors are presented on the Next Manufacturing Revolution website www.nextmanufacturingrevolution.org.

The Full Potential of Energy Efficiency for UK Manufacturing

The best practice total energy intensity savings for each sub-sector net of both sub-sector average energy intensity improvement and background improvements (see Figure 14) provides an estimate of the full potential energy saving available to UK manufacturers. The results for each sub-sector, based on 2010 energy spend, are presented in Figure 16. Note that the figures for paper printing & publishing, minerals, and mechanical engineering & metal products are conservative because the strong performance in annual savings above background were only recorded for a few years; evidence of longevity of these savings will support an upward revision of these estimates.

Figure 16: Full Potential of Energy Efficiency by UK Manufacturing Sub-Sector

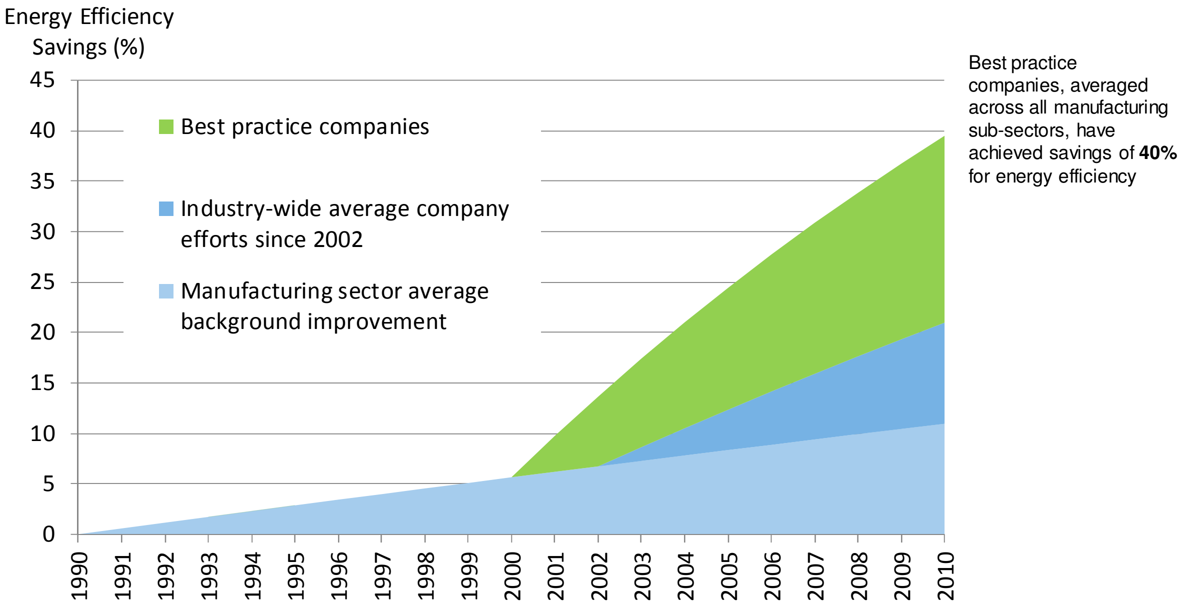


Source: Next Manufacturing Revolution analysis

For the entire UK manufacturing sector, the full potential annual saving based on 2010 energy spend is estimated at **£1.9 billion**, which is 20% of the sector's 2010 spend[31]. This saving could be substantially higher if energy prices continue their rapid rise.

An aggregated view of the opportunity for the UK manufacturing sector is shown in Figure 17, which illustrates the background efficiency improvements saving on average 10% of energy compared to 1990, company initiatives beginning around 2002 which saved a further 10%, and the further opportunities demonstrated by best practice companies of 20%.

Figure 17: Aggregated View of UK Manufacturing Energy Efficiency History



Sources: Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011; Next Manufacturing Revolution Survey responses; Literature review

Assuming a 2.4 year payback period (compare the average for opportunities identified in the Australian EEO program of 2.4 years[32] and just over two years implied by the 48% internal rate of return found by the Carbon Trust[33]), capital investment of **£4.6 billion** is required.

[31] Summarising the calculations: the average full potential opportunity based on best practice is 32% above background. 11% of this is already being captured as companies have stepped up their energy efficiency activities in the last decade in response to rising energy prices and shrinking margins in tough economic times. This leaves a further potential of 21%.
[32] Australian Department of Resources, Energy and Tourism (DRET), Energy Efficiency Opportunities Program Continuing Opportunities 2011: Results of EEO Assessments reported by participating corporations, DRET, 2012, p. 15.
[33] Carbon Trust Advisory Services, The Business of Energy Efficiency, Carbon Trust, c. 2010. http://www.carbontrust.com/media/135418/cta001-business-of-energy-efficiency.pdf

Comparing these figures with other research suggests that they are in the middle of the range of estimates (see Figure 18 for a summary):

- The Energy Efficiency Deployment Office (within DECC), in their Energy Efficiency Strategy[34] published in late 2012 estimate a range of potential energy savings for UK industry of 20 to 63TWh in 2020 – equivalent to 6% to 20% of 2011 consumption by the manufacturing sector. The results of this study are at the upper end of this range which is considered reasonable given that EEDO have assumed a range of take-up rates and allowed for a number of scenarios regarding addressing barriers to adoption.

- Analysis by the Energy Efficiency Financing (EEF) scheme, set up by Carbon Trust and Siemens Financial Services, estimated in 2013 that energy-efficient equipment can save the Industrial sector in the UK £2.2 billion per annum[35]. Broadly this compares favourably with the £1.9 billion in annual savings identified in this chapter, although the industrial sector is broader than the manufacturing sector examined in this study – which is countered to some extent by the savings identified in this study extending beyond equipment.

- The Carbon Trust, in their 2010 paper[36], note that based on their experience a large organisation can save 15% of their energy at an average internal rate of return of 48% through actions which are Incremental, Process/Systemic and Structural. These estimates support the results of this study, which also includes Core Redesign actions.

- The United Nations Industrial Development Organisation, in their 2009 energy efficiency benchmarking report, identified energy efficiency savings of 15% to 20% in developed nations through adopting best practice technologies in 26 industrial processes, products and industry sectors representing approximately 60% of global industry's final energy use[37]. This covers Process/System and Structural changes. This is consistent with, although slightly higher than, the findings of this study.

- Three recent sectoral studies have similarly identified potential savings of 15% to 20% in energy consumption. Saygin et al[38], looking at the global chemical and petrochemical sector, identified a 16% saving (compare the 9% improvement calculated in this study for the UK). Laurijssen et al[39], examining the Dutch paper industry on a process unit level, found 15% savings in energy use (compare 12% in this study). Aanda-Uson et al[40] estimated savings of 20% across the Spanish food and drink, textile, chemical and non-metallic mineral products sub-sectors (compare 28%, 37%, 9% and 7% in this study).

[34] Energy Efficiency Deployment Office, The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK, DECC, Nov 2012, p. 88.
[35] McGlone, C. 'Industrial sector haemorrhaging £2.2bn a year overpaying energy bills', edieEnergy, 6 March 2013, http://www.edie.net/news/6/Industrial-sector-overpaying-2-billion-every-year-energy-bills/.
[36] Carbon Trust Advisory Services, The Business of Energy Efficiency, Carbon Trust, c. 2010. http://www.carbontrust.com/media/135418/cta001-business-of-energy-efficiency.pdf.
[37] United Nations Industrial Development Organisation, Global Industrial Energy Efficiency Benchmarking: An Energy Policy Tool, UNIDO, 2010, p. xii.
[38] Saygin, D., M.K. Patel, E. Worrell, C. Tam and D. Gielen, Potential of best practice technology to improve energy efficiency in the global chemical and petrochemical sector, Energy, 36, 2011, 5779-5790.
[39] Laurijssen, J., A. Faaij and E. Worrell, Benchmarking energy use in the paper industry: a benchmarking study on process unit level, Energy Efficiency, 6, 2013, 49-63.
[40] Aranda-Uson, A., G. Ferreira, M. D. Mainar-Toledo, S. Scarpellini, and E.L. Sastresa, Energy consumption analysis of Spanish food and drink, textile, chemical and non-metallic mineral products sectors, Energy, 42, 2012, 477-485.

- DECC's electricity efficiency report[41] identified electricity efficiency savings potential for UK industry of 24% of electricity use, through Process/System and Structural change opportunities including technical improvement and usage optimization of motors, pump optimisation and improved boilers. This figure is greater than estimated in this study.

- The Ellen McArthur Foundation paper on the circular economy[42] calculated that the collection of 50% of mobile phones (of those, reusing 38%, remanufacturing 41%, and recycling 21%) would result in a 16% energy use reduction in mobile phone manufacturing. This is an example of a Core Redesign opportunity and indicates the substantial savings available from such initiatives – although the figure is larger than this NMR study indicates.

- Defra's study on the benefits of business resource efficiency estimated in 2009 that, for the manufacturing sectors examined, between 2% and 3.6% of energy use could be saved with a payback period of less than one year. This study extrapolated the energy efficiency audit results from the Carbon Trust. While recognising that the one year payback period limits potential savings to only some Incremental and Process/System opportunities, the results are more conservative than the findings of this study.

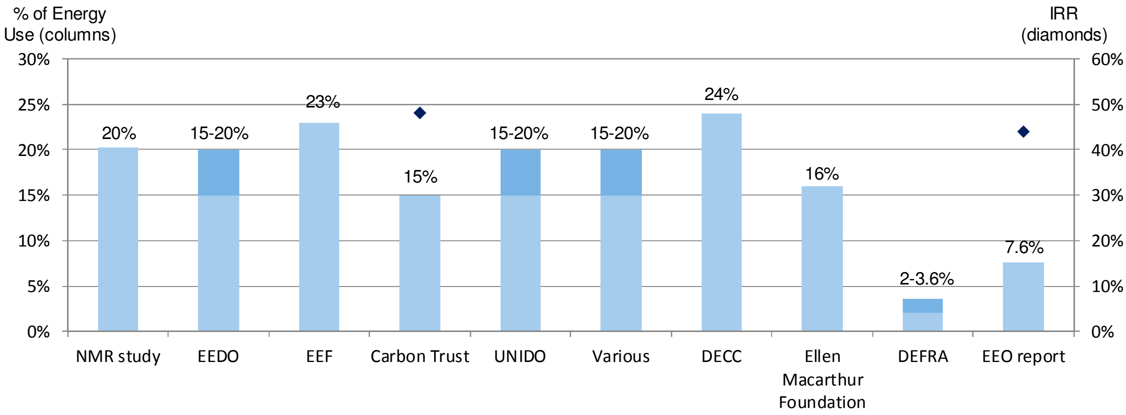
- The Australian Energy Efficiency Opportunities Act, 2006 requires high energy use companies to undertake energy efficiency assessments and report the opportunities identified that have a payback period of four years or less. For manufacturing companies assessed to the end of financial year 2011, which represented 13% of Australia's total energy use, new opportunities worth 7.6% of energy use were identified. Given that the four year payback period may preclude some Structural change and most Core Redesign opportunities, and the differing nature and maturity of Australian manufacturing compared to the UK, the EEO results broadly align with the findings of this study.

Figure 18 graphically summarises these comparators and illustrates the consistent support for the findings for this study given the differences in scope of the studies referenced.

[41] UK Department of Energy and Climate Change, Capturing the Full Electricity Efficiency Potential of the UK, DECC, 2012, pp. 8, 12, 17, 18.

[42] Ellen Macarthur Foundation, Towards a Circular Economy: Economic and business rationale for an accelerated transition, EMF, 2012, p.41.

Figure 18: Summary of Energy Efficiency Opportunities Identified in Recent Relevant Reports



Report date:	2013	2012	2013	c. 2010	2010	2011-13	2012	2012	2011	2012
Geography:	UK	UK	UK	UK	Global	Various	UK	Global	UK	Australia
Scope:	Manufac-turing	Industry	Industry	Large organisat-ions	Energy intensive industrial sectors	Specific sectors	Industrial sector, Electricity only	Mobile phone manufac-turers	Energy intensive manufac-turers, < 1 year payback	Energy intensive manufac-turers, < 4 year payback*
Opportunities included (grey tick indicates partly included):										
Incremental	✓	✓		✓		✓			✓	✓
Process & System	✓	✓		✓	✓	✓	✓		✓	✓
Structural	✓	✓	✓	✓	✓	✓	✓			✓
Core redesign	✓	✓				✓		✓		

*Some opportunities with >4 years payback were reported and included.

Qualitative surveys also support the existence of substantial energy efficiency savings:

- The Next Manufacturing Revolution survey (see Appendix 3 for details) showed that approximately 77% of the respondents had taken up Incremental opportunities, 67% had adopted Process/System opportunities, 60% were implementing Structural opportunities and 47% were addressing Core Redesign opportunities. This suggests that substantial further opportunities exist – especially in Structural change and Core Redesign which bring greater savings. Note that the results of the NMR survey probably understate the size of the opportunity because of the likely self-selection bias of respondents (who have good sustainability track records).

- Green Monday's 2011 Energy Efficiency White Paper survey of 102 senior sustainability and energy managers found that 51% of respondents estimated that their organisations had realised less than 33% of commercially viable energy efficiency opportunities, and 40% responded that their companies had tapped 33% to 66% of the opportunities[43].

Energy reduction has environmental benefits. In 2010, the UK manufacturing sector's greenhouse gas emissions from energy use was 96MtCO_2e[44]. A 20% reduction in manufacturing energy use would therefore represent a reduction in emissions of **19.2MtCO_2e** per year. Note that to

[43] Note that this sample included non-manufacturing companies. Source: Green Monday, Energy Efficiency White Paper, Green Monday, 2011, p. 3.

[44] Excludes freight transport fuel and industrial process emissions. Calculated by multiplying UK sub-sector fuel and electricity use by the total greenhouse gas emission factor for that type of fuel/electricity. Sources: DECC 270-ecuk-industrial-2010, Table 4.6c(i), http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx; Defra, 2012 greenhouse gas conversion factors for company reporting, May 2012.

understand the full greenhouse gas emissions impact of the Next Manufacturing Revolution, savings from transport efficiency, waste reduction and recycling need to be added – these are calculated in separate chapters of this study.

Energy efficiency also creates a range of societal benefits which include improved national energy security (through having to source less energy), eased load on transmission and distribution assets (especially at peak times), and reduced need for new assets including system reinforcement and power plants.

Energy efficiency also creates jobs undertaking the changes necessary in behaviour, processes, equipment and business approaches to reduce energy use. According to DECC[45], the energy efficiency sector in the UK accounted for 136,000 jobs and had sales of £17.6 billion in 2010/11. That means 7.7 jobs per million pounds spent annually.

This is consistent with the jobs data from other sources, with appropriate adjustment. For the UK, Consumer Focus in 2012 estimated that retrofitting homes for energy efficiency would generate 17.8 jobs per million pounds spent[46]. This is supported by the French Ministry for Ecology, Energy, Sustainable Development and Spatial Planning, who estimated in 2011[47] that for every one million euros of investment in property related thermal renovation, 14.2 jobs are created in energy related work (equivalent to 16.8 jobs per £1million at an exchange rate of 1.186€/£). These figures are expected to be significantly higher than average because domestic energy efficiency is more labour intensive.

Applying the 7.7 jobs per £1million spend on energy efficiency to the £4.6billion capital estimate of this study, and assuming it is spent over a 10 year period (and after which time equipment would need replacing), this would create **3,500 full time jobs**[48].

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[45] Energy Efficiency Deployment Office, The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK, DECC, Nov 2012, p. 7.

[46] Consumer Focus, Jobs, growth and warmer homes. Evaluating the Economic Stimulus of Investing in Energy Efficiency Measures in Fuel Poor Homes, 2012. Cited in Fawkes, S. Energy Efficiency: The Definitive Guide to the Cheapest, Cleanest, Fastest Source of Energy, Gower, 2013.

[47] L'Union Social pour l'Habitat, Plan européen pour la relance économique COM(2008) 800 final Mesure n°6 : Améliorer l'efficacité énergétique dans les bâtiments. Reprogrammation des programmes opérationnels régionaux des Fonds structurels en faveur des logements sociaux, 2011. Cited in Fawkes, S. Energy Efficiency: The Definitive Guide to the Cheapest, Cleanest, Fastest Source of Energy, Gower, 2013.

[48] It is assumed that the majority of these jobs will be within manufacturing companies because energy efficiency experts require a good knowledge of the company's operations/equipment and the need for the expertise will be ongoing.

Barriers to the Full Adoption of Energy Efficiency

There are four key barriers to achieving the full potential of energy efficiency[49], which are interdependent:

1. **Senior executive leadership**.

   The effort to pursue all attractive opportunities and the behaviour change necessary to achieve a company's full potential requires senior executive support for resource (including energy) efficiency. Without it, 'business as usual' continues because fully addressing energy efficiency requires:
   - Action by multiple functions and all divisions within an organisation (and therefore requires the reach of senior executives)
   - Changed behaviours and cultures (best led by the most senior executives)
   - Investment in skills and equipment (often requiring approval from senior executives)
   - Commitment backed up by performance measures, including KPIs, cascaded through the organisation (which can only be initiated by senior executives)

   The primary importance of senior executive leadership was explicitly noted in the peer review process for this study and in the literature, because without it, all of the other barriers are seen to be much more difficult to address.

   > "The first enabling condition [for energy management], and the most important, is explicit leadership, i.e. full support from top management. … Without the explicit support of the leadership of the organisation, and appropriate resources being dedicated to energy efficiency, these significant opportunities will remain an underexploited source of profit, reduced emissions and potential employee engagement."[50]

   Pioneering companies in resource productivity have often been led by CEOs with deep and public commitment to sustainability. Examples in the UK include Paul Polman (Unilever) and Ian Cheshire (Kingfisher) and internationally Ray Anderson (Interface), Yvon Chouinard (Patagonia) and Gunter Pauli (Ecover).

   While middle management is technically equipped to address resource conservation, in many cases it can be resistant to change because of a range of structural factors:
   a. Decades of downsizing means that middle managers have limited bandwidth for non-core initiatives, as well as keeping up with the latest technologies and approaches
   b. They have tightly defined, bonus-linked key performance indicators which mostly drive short-term behaviour and a heightened sensitivity to risk

[49] Sources include: Pew Center for Global Climate Change, From Shop Floor to Top Floor: Best Practices in Energy Efficiency, 2010; UK Department of Energy and Climate Change, Capturing the Full Electricity Efficiency Potential of the UK, DECC, 2012; UK Department for Environment, Food and Rural Affairs, The Further Benefits of Business Resource Efficiency, DEFRA, 2011; Lavery, G., Pennell, N., Ahmed, S., Unlocking the Full Potential of Energy Efficiency, Booz & Company, 2010; World Economic Forum, Repowering Transport: Project White Paper, WEF, 2011; Australian Government, Report of the Prime Minister's Task Group on Energy Efficiency, July 2012, www.climatechange.gov.au; Next Manufacturing Survey.
[50] Fawkes, S. Energy Efficiency: The Definitive Guide to the Cheapest, Cleanest, Fastest Source of Energy, Gower, 2013.

c. They perceive, often correctly, that the systems they manage are optimised; they do not have decision rights over multiple systems or core product redesign to be able to capture greater savings
d. Savings that require co-operation between often distant middle managers, such as facilities managers and production managers, are always challenging
e. Leading a culture change initiative (required for incremental energy efficiency savings) can be perceived as a threat to the authority of senior executives

Resource efficiency therefore needs to be addressed, or at the very least initiated by, the CEO/COO/CFO. Historically, it has been fragmented into its constituent elements (energy, waste, etc.) resulting in smaller benefits, which are less worthy of CEO attention and seen as technical issues which fall within the remit of middle management. Further, the CEO requires conviction and external evidence (information) of the opportunities available, because the technical advice from internal management will be biased against change for the above reasons.

2. **Information**. Several different types of information are required for an energy efficiency solution to be considered, including: knowledge that energy saving approaches/equipment exist, that they work, their risks, case studies demonstrating performance in similar circumstances, knowledge of who can supply the solution, the full potential of the opportunities available, best practices and trusted data on costs. This information must be readily available and/or obtained from reliable sources because busy executives and engineers cannot reasonably be expected to stay abreast of rapidly emerging new technologies, processes and approaches.

   Information also includes internal performance data which enables opportunities for improvement to be identified.

   Information on hidden costs and risks is a specific requirement; energy efficiency projects often involve hidden transaction costs such as project development time, shut-down time, other disruptions to business as usual and risks to warranties covering other equipment. These must be understood and quantified to the extent possible, so that the investment case is robust and truly representative. The cost of bringing all of the necessary skills together must also be included (see points 3 and 4 below).

   It must be noted that energy efficiency also brings a range of **hidden financial benefits** to energy systems, including improved energy security, eased load on transmission and distribution assets and reduced need for new assets including line reinforcement and power plants. Historically these benefits have not been able to be directly included in the economics of energy efficiency projects due to their external nature and the disaggregated nature of the UK's energy delivery system.

3. **Appropriate skill mix**. Energy efficiency projects require a mix of capabilities that may already exist within manufacturers, but are rarely brought together around a single challenge. Skills required include:

   a. Engineering/technical know-how to identify technical solutions for ancillary as well as core production activities, fit them into business circumstances and de-risk them.
   b. Commercial skills to develop robust investment cases to secure funding in tight economic conditions and to identify new business models.

c. Change management skills to educate staff, motivate new behaviours, stimulate action in many instances beyond business-as-usual activities and secure support for projects.
d. A systems perspective that enables the organisation to look beyond single-unit improvements to find cross-system optimisation opportunities.

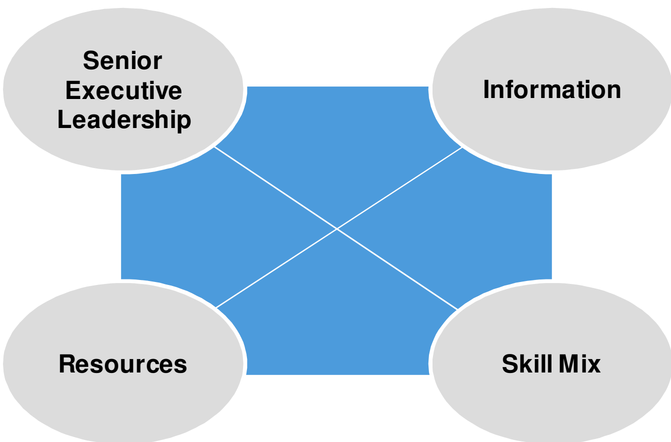
It must be noted that the skill mix must also include a sufficient amount of each skill. For example, if engineering resources are limited, engineers can design equipment for the heaviest loading occurrence and then replicate the design across a facility – meaning that the equipment can be substantially overdesigned (and therefore run inefficiently) for most applications.

4. **Resources**. Most energy efficiency projects require project funding including to cover the cost of solution development, design and capital expenditure. Even though Incremental and Process & System initiatives can have a rapid payback period and the savings generated can be used to help fund later, slower payback projects, some initial investment is still required.

   Common energy efficiency funding issues include:
   - Companies having cash limits and not being prepared to consider alternative financing, despite attractive returns
   - Unrealistically high hurdle rates being applied, despite the low and controlled risk involved in energy efficiency projects
   - All benefits (including, for example, the value of greenhouse gas emissions savings) not being included in business cases
   - Efficiency projects are deprioritised in favour of other investment options (such as plant expansion or new product development).

These barriers must all be addressed if the potential of energy efficiency is to be achieved. All are interrelated and mutually reinforcing; to address only some is not sufficient (see Figure 19).

Figure 19: Energy Efficiency Barrier Ecosystem



To illustrate the need to address all four barriers, consider the Australian Energy Efficiency Opportunities (EEO) Act 2006. It mandates that large energy users must conduct assessments of their energy use, to identify and report on the energy efficiency opportunities that are available with a payback period of less than four years, including the savings and capex requirements for each. This overcomes the information and senior executive support issues. However, it is only resulting in half

(54%) of identified opportunities being taken up, with 30% of the opportunities with less than two years payback not being implemented[51]. This demonstrates that addressing just some of the key barriers results in only partial adoption of opportunities.

A range of other issues have been suggested as barriers, but are considered to be symptoms of the above-discussed four barriers, rather than barriers in their own right. These include:

- Lack of time (a function of lack of senior executive leadership and resources)
- Lack of interest/prioritisation (a function of lack of senior executive leadership)
- Product availability (a function of lack of information)
- Lack of skilled personnel (a function of inappropriate skill mix, lack of information and/or inadequate resources to afford the necessary expertise)

Note that the agency or split incentive issue common in other sectors is not generally considered to be applicable in the manufacturing sector[52].

[51] Australian Government Department of Resources, Energy and Tourism, Energy Efficiency Opportunities Program Continuing Opportunities 2011: Results of EEO Assessments Reported by Participating Corporations, DRET, 2012.

[52] UK Department of Energy and Climate Change, Capturing the Full Electricity Efficiency Potential of the UK, DECC, 2012, pp. 36-38.

Chapter 4: Process Waste Reduction

This chapter considers by-products and rejects created during the manufacturing process. Post-consumer product management is discussed in the Circular Resource Use chapter.

Chapter Summary

Total UK manufacturing waste was 22.7 million tonnes in 2008.

From 2002 to 2009 in England, total waste halved and waste sent to landfill dropped by two thirds, driven in large part by legislation and significant increases in landfill taxes which have made landfilling the most expensive disposal option for non-hazardous waste.

However, substantial profitable waste reduction opportunities worth **£800 million p.a.** remain:

- Four manufacturing sub-sectors (food, beverage & tobacco; wood and wood products; non-metallic mineral products, and; furniture and other manufacturing) reduced their total waste by less than 20% from 2002 to 2009. Bringing these to best practice is estimated to save £480 million p.a. in avoided material costs.
- Zero waste to landfill has now been achieved by leading companies in most manufacturing sub-sectors; taking companies to this level would save the UK manufacturing sector £250 million every year in avoided landfill costs (which is in addition to the avoided materials costs above).
- Best practice companies are achieving healthy revenues from the sale of their waste. Achieving these across the board would result in additional company profits of £70 million per annum.

Adopting good practice in process waste reduction and management would reduce greenhouse gas emissions by **2.6 MtCO_2e per year** through avoided embodied emissions in wasted product and avoided landfill methane.

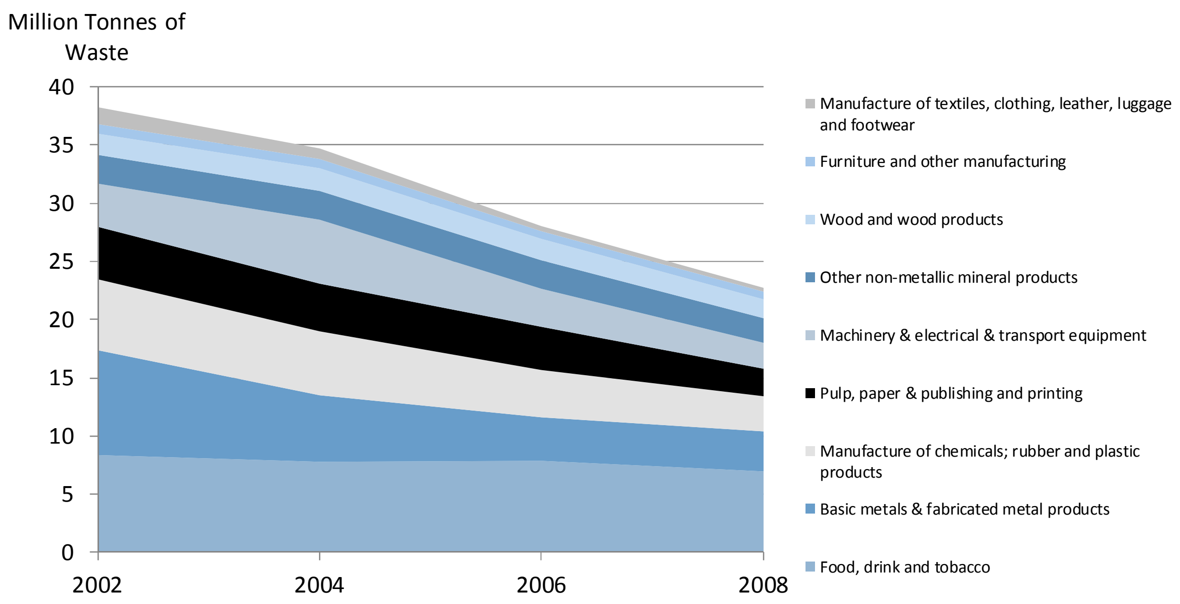
Reducing waste also results in social benefits such as reduced danger of landfill contamination and fewer disposal sites.

Five inter-related barriers exist to substantially reducing process waste: senior executive leadership, information, product design, skills and infrastructure. All of these must be addressed simultaneously to unlock the benefits available.

UK Manufacturing's Waste Generation and Intensity Trends

Since the first authoritative quantification of manufacturing sector waste in the UK in 2002, the absolute volume of waste declined by 40% to 22.7Mt in 2008[53]. Figure 20 presents this decrease.[54]

Figure 20: Historical UK Waste Generation by Manufacturing Sub-Sector

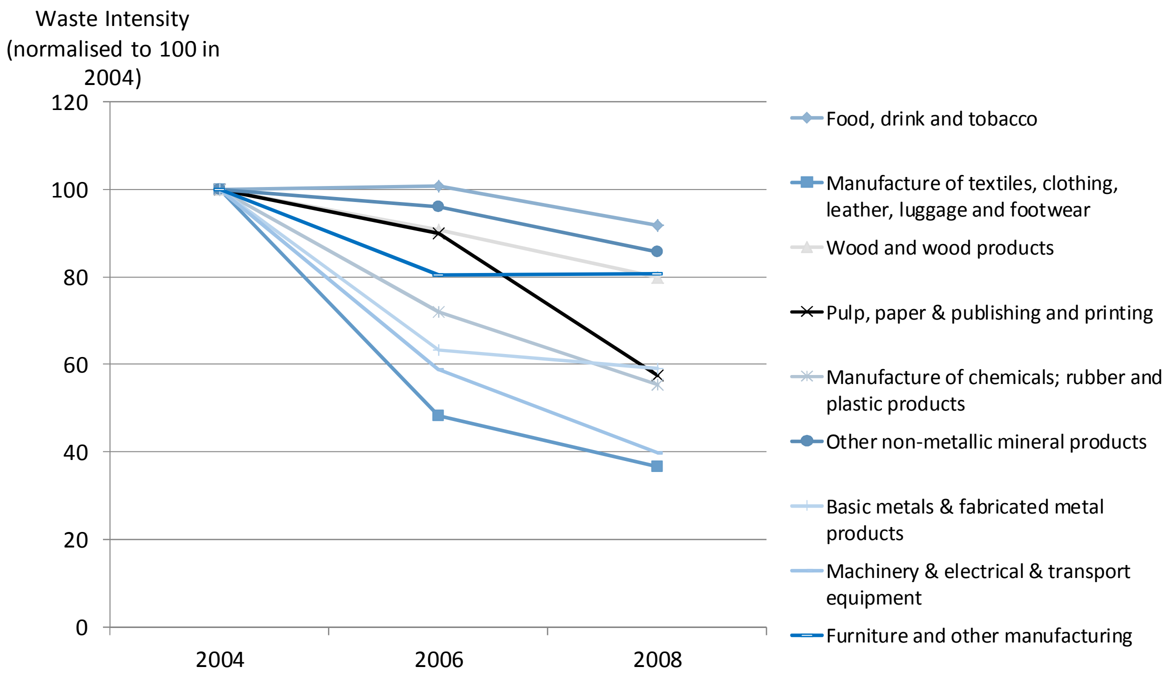


Source: Defra, Waste generated by sector, 2009.

However, the decline of waste intensity[55] in each of the manufacturing sub-sectors has varied (see Figure 21).

[53] This includes both hazardous and non-hazardous waste, and includes waste that is recycled, reused and converted to energy.
[54] Note that the 2004, 2006 and 2008 figures are not survey data, but were modelled as part of the study commissioned by Defra. However, for industrial waste the modelled data appears to accurately reflect the changes in survey data from 2002 to 2009.
[55] Waste intensity was calculated as the weight of waste divided by the Index of Production for each manufacturing sub-sector for each year to normalise for production output.

Figure 21: UK Waste Intensity by Manufacturing Sub-Sector[56]



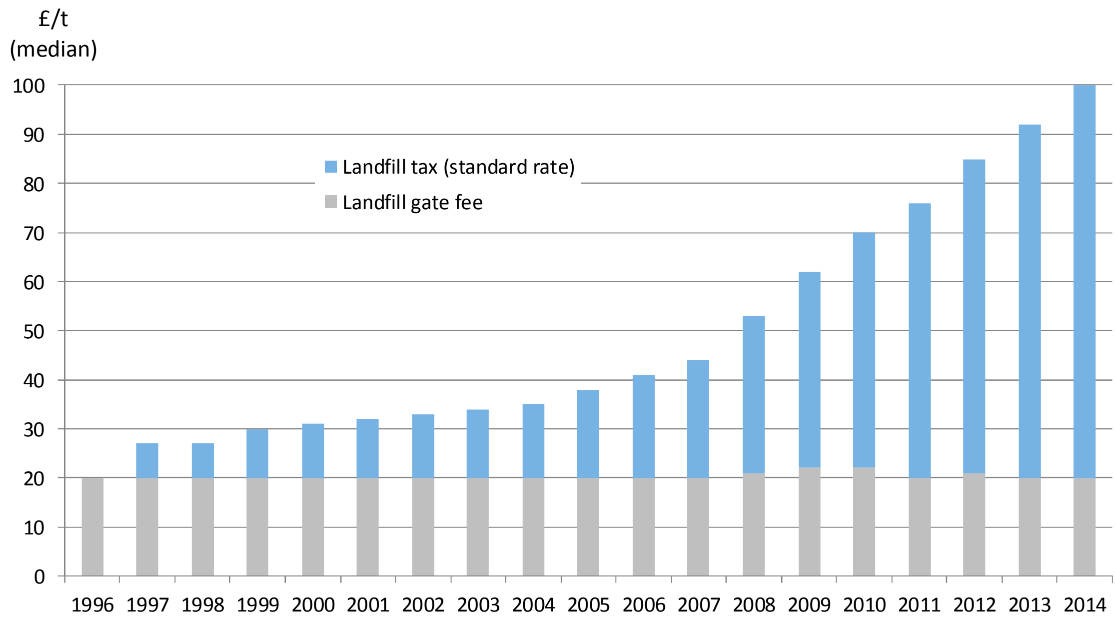
Sources: Defra, Waste generated by sector, 2009; Office of National Statistics, Detailed Indices of Production, 2011

A key motivator for this substantial improvement across many sub-sectors can be found in the rapidly increasing price of landfill disposal (see Figure 22), driven by the escalating landfill tax introduced to assist the UK to achieve its obligations under the European Commission's Landfill Directive[57].

[56] 2004, 2006 and 2008 figures are not survey data, but were modelled as part of the study commissioned by Defra. However, for industrial waste the modelled data appears to accurately reflect the changes in survey data from 2002 to 2009.

[57] For more information about the Landfill Directive refer to Council Directive 1999/31/EC of 26 April 1999.

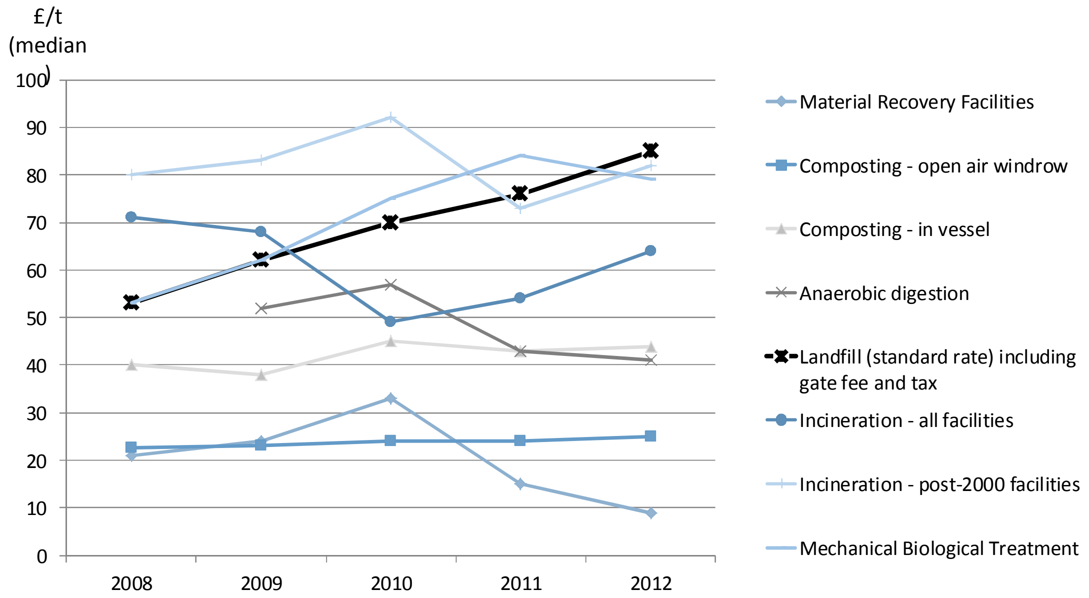
Figure 22: Landfill Prices over Time[58]



Notes: Landfill gate fees before 2008 and after 2012 have been extrapolated from 2008 to 2012 actual median data. Landfill tax is taken mid-year (i.e. after 1 April escalation date)
Sources: HMRC, Notice LFT1: A General Guide to Landfill Tax, July 2012; WRAP UK Annual Gate Fee Reports 2008 to 2012

The impact of the landfill tax has been to make landfilling the most expensive of the conventional disposal options from 2012 onwards (see Figure 23). This has also made alternative treatment technologies more economically viable.

Figure 23: UK Waste Disposal Costs



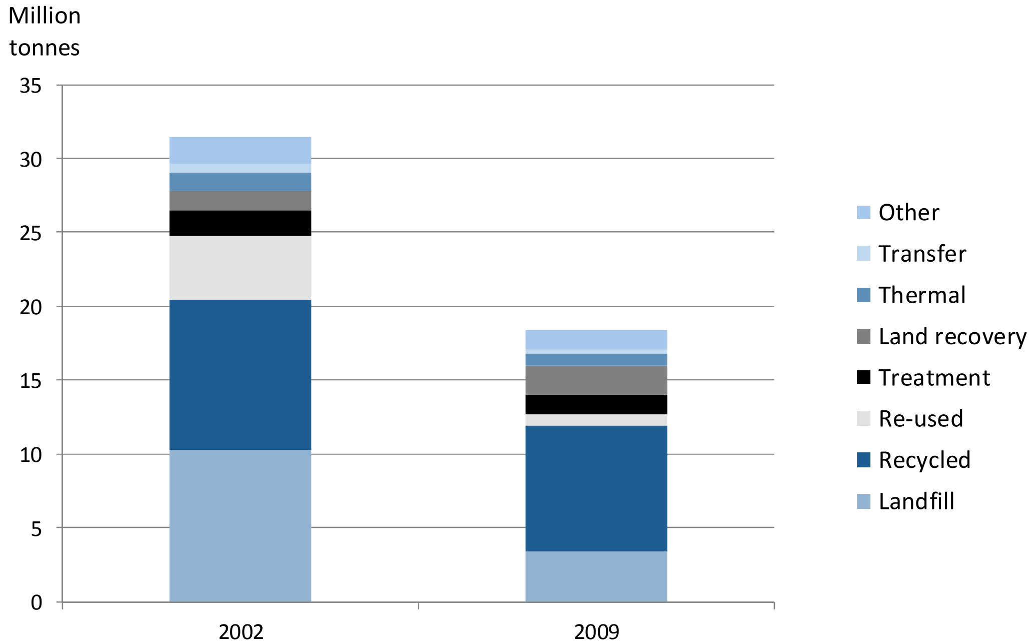
Note: Landfill tax is taken mid-year (i.e. after 1 April escalation date)
Source: WRAP UK Annual Gate Fee Reports 2008 to 2012

[58] Note that the landfill tax will rise with inflation after 2014.

In addition, to encourage companies to reduce the process waste they generate, the Waste (England and Wales) Regulations 2011 require any business that produces or handles waste to take all reasonable measures to apply the waste hierarchy[59]. This is enacted when waste is transferred to another person, with Duty of Care Transfer Notes and Hazardous Waste Consignment notes requiring a declaration confirming that the hierarchy has been applied. If asked by the Environment Agency, waste producers and managers need to explain in detail how their waste decisions are consistent with application of the hierarchy.

The response of manufacturers to increased landfill charges and tightened regulations is illustrated in Figure 24 which shows manufacturing waste figures for England (which contributes around 85% of UK manufacturing waste). From 2002 to 2009, there was a halving of total manufacturing waste and a two thirds reduction in landfilling. Both of these types of improvement unlock significant value for companies – through reduced need for raw materials and avoided landfill costs.

Figure 24: Manufacturing Waste in England by Disposal Type[60]

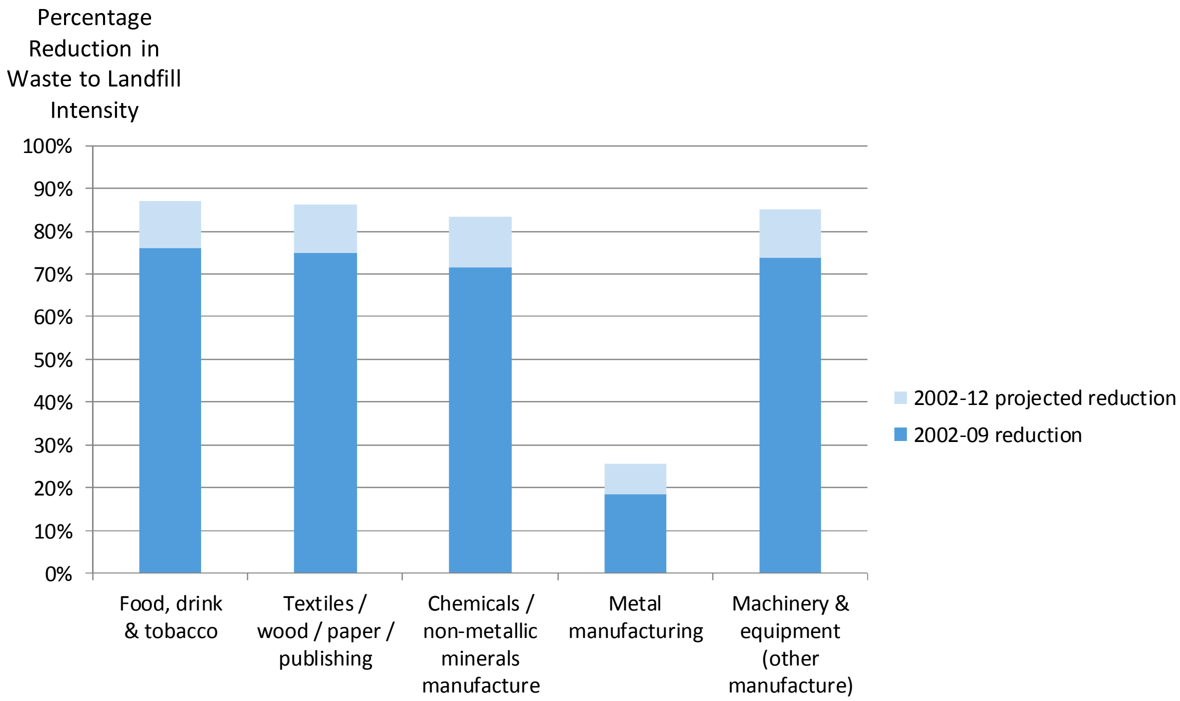


Source: Defra, Waste generated by sector, 2009; Defra, Waste by sector and management method, 2002

[59] The waste hierarchy used by Defra, the Waste and Resources Action Program (WRAP) and others is: Prevention (avoid & reduce), Re-use, Recycle , Recover, Dispose.
[60] It is not clear why there was a substantial drop in re-use between 2002 and 2009.

Examining waste to landfill intensity[61] in more detail, most manufacturing sub-sectors made substantial reductions of around 75% between 2002 to 2009; projecting forwards at the same rate of improvement suggests a reduction of around 85% from 2002 to 2012 (see Figure 25)[62]. The metal manufacturing sub-sector is a notable exception to these improvements, with around 20 to 25% reduction in waste to landfill.

Figure 25: Waste to Landfill Intensity by Manufacturing Sub-sector since 2002



Source: Environment Agency, National Waste Production Survey 2002; Defra, Survey of Commercial and Industrial Waste Arisings for 2009, 2010

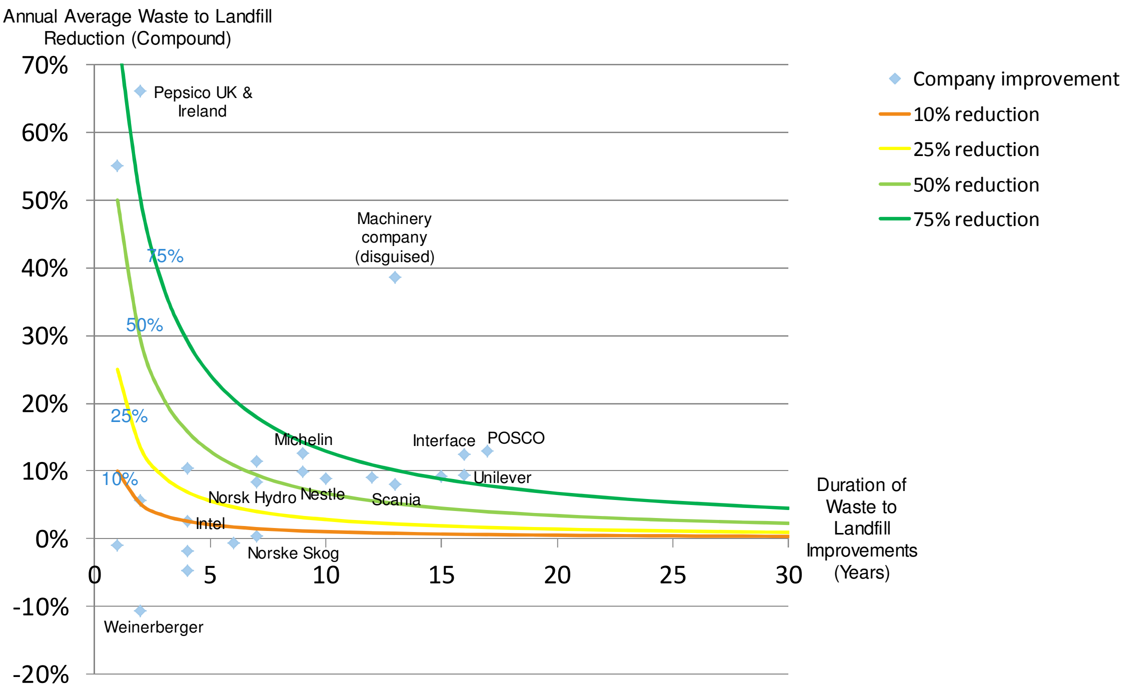
These substantial sub-sector average improvements demonstrate that, on average, most manufacturing companies in the UK have acted to address their waste to landfill.

[61] Waste to landfill intensity is the waste to landfill divided by the Index of Production for each sub-sector. This normalised approach enables comparisons to be made over time on a like-for-like production volume basis.
[62] Note that the sub-sectors shown are the most granular for which data is available.

Company Waste to Landfill Intensity Performance

Blue chip companies around the world have a mixed record in addressing waste to landfill (see Figure *26*).

Figure 26: Company Waste to Landfill Reduction Comparison



Note: Un-named or disguised datapoints are companies who provided data confidentially or are not named for other reasons.
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review

Best Practice in Waste Reduction

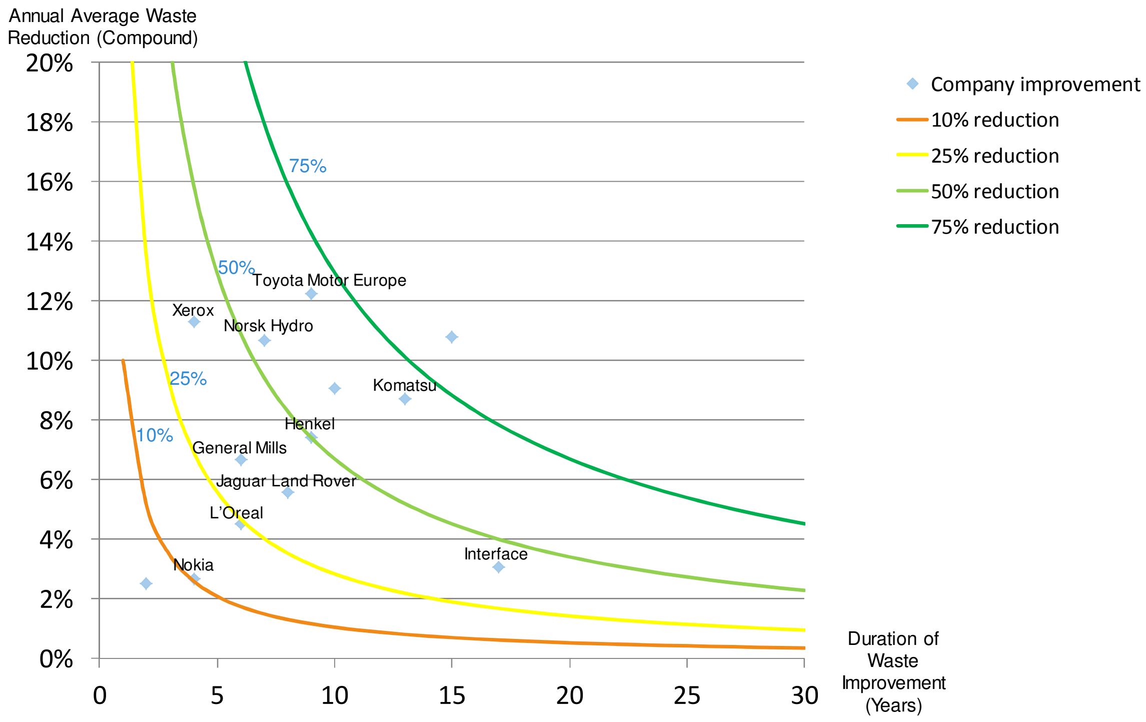
While the performance of many of these businesses is laudable, a range of companies have achieved zero waste to landfill, at least at a number of sites. Locally, these include Tarkett, Nampak Plastics, British Gypsum, Pepsico UK and Ireland at 11 sites, Toyota Motor Europe at 8 sites, Caterpillar at 2 UK sites, and FMC Technologies at their Dunfermline plant in Fife[63]. Internationally, General Motors has achieved zero waste to landfill at 102 sites globally and claims that it now generates $1 billion a year from the reuse and recycling of production by-products[64].

Examples of zero waste to landfill companies or plants exist globally for all sub-sectors with the exception of metal manufacturing, for which best practice is POSCO with a 91% reduction in waste to landfill, over time.

Beyond waste to landfill, many companies around the world have made significant reductions in their overall waste volumes. For example, Toyota Motor Europe reduced its total waste per vehicle by 70% in ten years[65] . Further examples are shown in Figure 27.

[63] Sources: Company websites; Zero Waste Scotland.
[64] Kaye, L., GM's Recycling Division Now Generates $1B Annually, Triple Pundit, 21 October 2012, http://www.triplepundit.com/2012/10/gm-zero-waste/
[65] Evans, S., Burgendahl, M.N., Gregory, M., Ryan, C. Towards a Sustainable Industrial System, University of Cambridge Institute for Manufacturing, 2009.

Figure 27: Waste Reduction by Company



Note: Un-named datapoints are companies who provided data confidentially or are not named for other reasons.
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review

How Good Practice Companies Reduced their Process Waste

Good practice companies tend to focus on three activities (which combine elements of the waste hierarchy[66]) to reduce their waste and impact on the environment while improving profitability:

1. **Prevention.** First, they work to avoid process waste. To do this they typically address four types of waste saving opportunities, each differing in ease and investment requirement:

    i. **Incremental**. These opportunities involve mostly behaviour and cultural change, such as monitoring waste, separating streams, identifying and rectifying anomalous behaviour, and educating and encouraging staff to avoid waste. Often these incremental opportunities are referred to as "quick wins" because they can be implemented quickly, do not involve capital expenditure, and frequently create tangible savings.

    ii. **Processes and Systems**. Waste improvements that involve changes in processes fall into this category, such as establishing a waste management program/team, changing operating procedures to reduce waste (e.g. during line start-up/shut-down), lean production, just-in-time ordering, and setting up waste reporting systems and targets. Many of these savings are inexpensive in capital terms, but can result in substantial savings.

[66] The waste hierarchy used by Defra, the Waste and Resources Action Program (WRAP) and others is: Prevention (avoid & reduce), Re-use, Recycle , Recover, Dispose.

iii. **Structural Change**. Where new equipment or production process redesign is involved, this is structural change for a company – often involving capex and usually occurring as part of scheduled maintenance or replacement. Typical areas of opportunity in the manufacturing sector include installing more precise process equipment (e.g. heaters which can be better controlled to avoid over-cooking products; more precise cutters) and redesign of production processes to reduce waste such as moving from a manual to an automated process.

iv. **Core Redesign**. Altering the core of a business, such as redesigning products to increase the recyclability of components or changing a company's business model (e.g. service delivery versus product) are fundamental changes which can lead to the greatest waste savings. Not making a product reduces the waste associated with the product.

2. **Re-use/Recycle/Recover.** Where waste is unavoidable, eliminating the cost of landfilling by finding new homes for waste streams is a second focus for good practice companies. For example, solid non-hazardous waste can be used in road base and a range of other applications; combustible materials can be used as fuel to produce energy.

   Best practice companies work to increase the value (both economic and environmental) of their waste, seeing it not as a problem, but instead as a product stream to be monetised. For example POSCO, the Korean steel manufacturer, is marketing and selling its blast furnace slag[67] as an environmentally-friendly cement substitute called PosMent, which is of better quality than existing slag cement. POSCO claims that PosMent has 70% less carbon emissions than traditionally produced cement[68]. For some manufacturers, up-selling may require switching input materials so that waste streams can create greater revenues. Note that the best up-selling opportunity is to convert waste back into raw materials for the plant – saving on transport and external processing costs as well as avoiding expensive new material costs.

Further process waste examples for a range of manufacturing sub-sectors are presented on the Next Manufacturing Revolution website www.nextmanufacturingrevolution.org on the Case Studies tab.

The Full Potential of Process Waste Reduction for UK Manufacturing

Comparing UK sub-sector average practice against best practice for value-adding activities enables the full potential value from process waste reduction to be calculated for UK manufacturing.

1. **Avoided loss of raw materials**

   As seen in Figure 21, the majority of sub-sectors reduced their total waste by between 40% and 70% from 2004 to 2008. This is consistent with the good practice companies examined. However, four sub-sectors (food, beverage & tobacco; wood and wood products; non-metallic mineral products, and; furniture and other manufacturing) achieved less than 20% improvement. These sectors represent an opportunity for improvement, by taking their waste prevention to best practice.

[67] Note that blast furnace slag has been declassified in the UK as a waste recently.
[68] POSCO, 2011 Report, p. 43.

The largest opportunity amongst these is in food, beverage and tobacco, where total purchases of goods, materials and services in 2010 were £62 billion[69]. This sub-sector's average reduction in process waste production from 2004to 2008 was 8.2%. Within this sub-sector, General Mills achieved a reduction in total waste of 34% in 6 years. Applying the same compound annual improvement rate for just 4 years, to coincide with the 2004 to 2008 period, suggests a saving figure of 24.2%. Assuming an average wastage rate of 4% of materials[70], the value of potential savings to the UK food, beverage and tobacco sub-sector from lifting their performance to best practice is £397 million per annum[71].

Applying the same best practice figure of 24.2%[72] and wastage rate of 4%[73] to the wood and wood products, non-metallic mineral products, and furniture and other manufacturing subsectors yields annual potential savings of £31 million, £38 million and £18 million respectively.

The combined total for just these four sub-sectors is therefore estimated to be **£480 million** per annum.

2. Avoided landfill fees

Extrapolating the 2002 to 2009 rates of waste to landfill reduction to 2012 (as per Figure 25) enables calculation of the landfill savings available in 2012. Taking all manufacturing sub-sectors (except metal manufacturing) to zero waste to landfill, and reducing the metals sub-sector 91% below 2002 waste to landfill levels (as per POSCO) would save UK manufacturing **£250 million** per annum at 2012's £85 per tonne landfill fee plus £10 per tonne haulage. Increasing the fee to the planned £100 per tonne in 2014 (the maximum amount set in current legislation) increases this to £288 million per annum. The savings per sub-sector are shown in Figure 28.

3. Revenues from sale of waste

Key to estimating revenues for waste is the price per tonne of waste, which varies by manufacturing sub-sector due to the different inputs involved:

- For the food, beverage and tobacco sub-sector where the majority of process waste is biodegradable, the price of compost has been used as an approximate price for waste at £7.50 per tonne[74].
- Inputs of the textiles/wood/paper/publishing processes are mostly combustible, so the price for woodchips has been used to value waste from this sub-sector at £11 per tonne[75].

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[69] Office for National Statistics, Annual Business Survey: Section C - Manufacturing, 2011.

[70] 4% is the waste figure for Nestle (see their 2011 Creating Shared Value report, p. 215); it would be too conservative to use the 3.55% wastage rate of General Mills to represent industry average given their significant improvements.

[71] Calculated as: £62bln x (24.2%-8.2%) x 4% = £397 mln.

[72] Considered to be a reasonable and conservative assumption given the observed best practice improvements in other sub-sectors in less than a decade: 41% in the manufacture of textiles, 50% in the manufacture of chemicals, 55% in the manufacture of basic metals, 70% in the manufacture of transport equipment, and 70% in the manufacture of other equipment. See Figure 27.

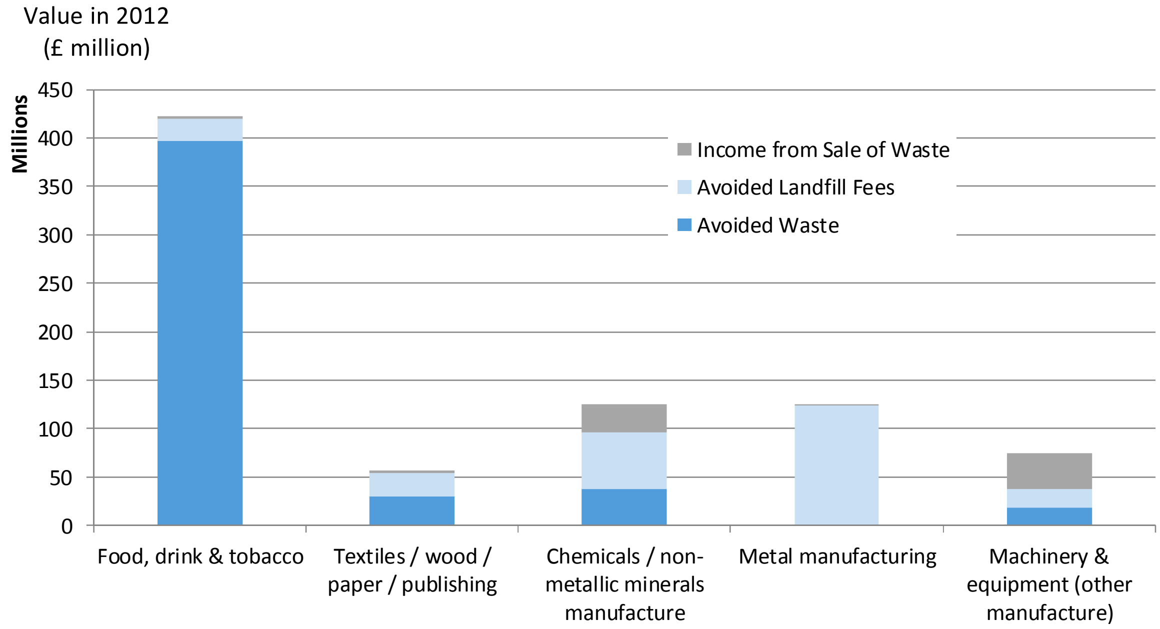
[73] Note that waste figures for these specific sub-sectors were not available. The 4% waste figure is considered a reasonable assumption given the waste observed in other analogous sub-sectors (e.g. Jaguar Land Rover at 3%, Norsk Hydro at 3.2%, Toyota Europe at 3.6% and Komatsu at 7.4%), especially since these companies have achieved substantial reductions in their total waste over the last decade and so these figures are after concerted efforts.

[74] Source: WRAP UK at http://www.wrap.org.uk/content/organics-0, June 2012 figures used.

- For chemicals and non-metallic minerals, the price for coloured PET (which is a fraction of the price of clear PET) was used as a sub-sector average waste price, at £47.50 per tonne[76].
- Despite blast furnace slag being worth £11 per tonne[77], metal manufacturing creates a great deal of low value waste. POSCO's income from sale of waste amounted to just £0.22 per tonne[78]. To be conservative, this lower figure was used in the value calculations.
- For machinery and equipment manufacture, the price of scrap metal varies from £150 to £200 per tonne[79]. While this appears high, it is supported by the reported waste revenues of Komatsu and Scania at £285 and £168 per tonne respectively[80]. A conservative rate of £150 per tonne was used in this analysis.

Applying these prices to the volumes of waste going to landfill in 2012 that will transition to zero waste to landfill (with the exception of the metals sub-sector which is assumed to move to a 91% saving below 2002 levels), minus the avoided waste to avoid double counting, results in a revenue (and profit) increase for UK manufacturers conservatively estimated at **£70 million** (for the sub-sector split see Figure 28)

Figure 28: Combined Waste Reduction Financial Benefits Available to UK Manufacturing



Sources: Next Manufacturing Revolution analysis

In 2012, the combined value of these three benefits is **£800 million**.

[75] Source: http://www.bioregional.com/files/publications/WoodChipProduction_Apr06.pdf, 2006. Prices are ex-yard.
[76] Source: http://www.letsrecycle.com/prices/plastics/, September 2012 figures used.
[77] Source: http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel_slag/mcs-2012-fesla.pdf, 2011 figure used.
[78] POSCO Annual Report, 2011, p. 199.
[79] Source: http://www.letsrecycle.com/prices/metals, 16 October 2012 figures used.
[80] Komatsu, Sustainability Report, 2012, p. 48; Scania, Annual Report, 2011, pp. 50-51.

Comparison with other research shows support for the above figures:

- A 2003 report for the Environment Agency identified £2 to £2.9 billion savings in annual operating cost if UK manufacturers were to invest in best-practice waste minimisation techniques[81]. Figure 20 and Figure 24 suggest that UK manufacturing has seized many of these opportunities and the reduced figure of £480 million calculated in this study therefore appears reasonable.

- Case studies under the Government's Envirowise resource efficiency program demonstrated that the program helped companies save, on average, £217 million p.a. and that an investment by a business to address resource efficiency has a usual payback period of twelve months or less[82]. The magnitude of this saving is consistent with the calculations of this study. Typical savings across all sectors were found to be: reduced purchase of raw materials, sale of recovered product, reduced management costs, and reduced waste disposal costs – broadly consistent with the value areas examined in this study.

- DEFRA's study on the benefits of business resource efficiency[83] in 2009 estimated that the value of avoided landfill fees for the Commercial and Industrial sectors was £445 million. Pro-rating down to the manufacturing sector alone based on volume of waste, this figure becomes £165 million. Adjusting landfill fees from the time of the study (£70 per tonne) to £85 per tonne in 2012 gives a figure of £201 million – within 20% of the £250 million calculated above. Note that this Next Manufacturing Revolution study has recognised that while further reduction in waste to landfill has occurred since 2009, best practices have also improved in this period, with zero waste to landfill now a reality in many companies.

Qualitative surveys of manufacturing companies also support the existence of substantial process waste reduction opportunities:

- The EEF, in their Measuring Performance Environment Survey in 2009, found that 50% of companies had waste reduction programs and reuse/recycling programs across their whole organisations[84]. This suggests that at least half of companies have improvement opportunities.

- The Next Manufacturing Revolution survey[85] results (see Figure 29) suggests that most aspects of waste good practice examined in this chapter are being done by 50% to 75% of respondents[86]. This is consistent with the significant reductions in waste and waste to landfill achieved since 2004, but also indicates that substantial economic benefits remain untapped.

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81 Cambridge Econometrics & AEA Technology, The benefits of greener business: The cost of unproductive use of resources, Environment Agency, 2003, cited in Towards greater resource efficiency in the East of England, Draft version 2 October 2004 at http://www.insighteast.org.uk/WebDocuments/Public/approved/user_729/Towards_greater_resource_efficiency_in_the_EastofEngland-finalsummary.pdf

82 Insight East, Towards greater resource efficiency in the East of England: A strategic framework and current activity in resource efficiency and waste market development in the context of the emerging regional economic strategy, Version 2 October 2004, p. 5.

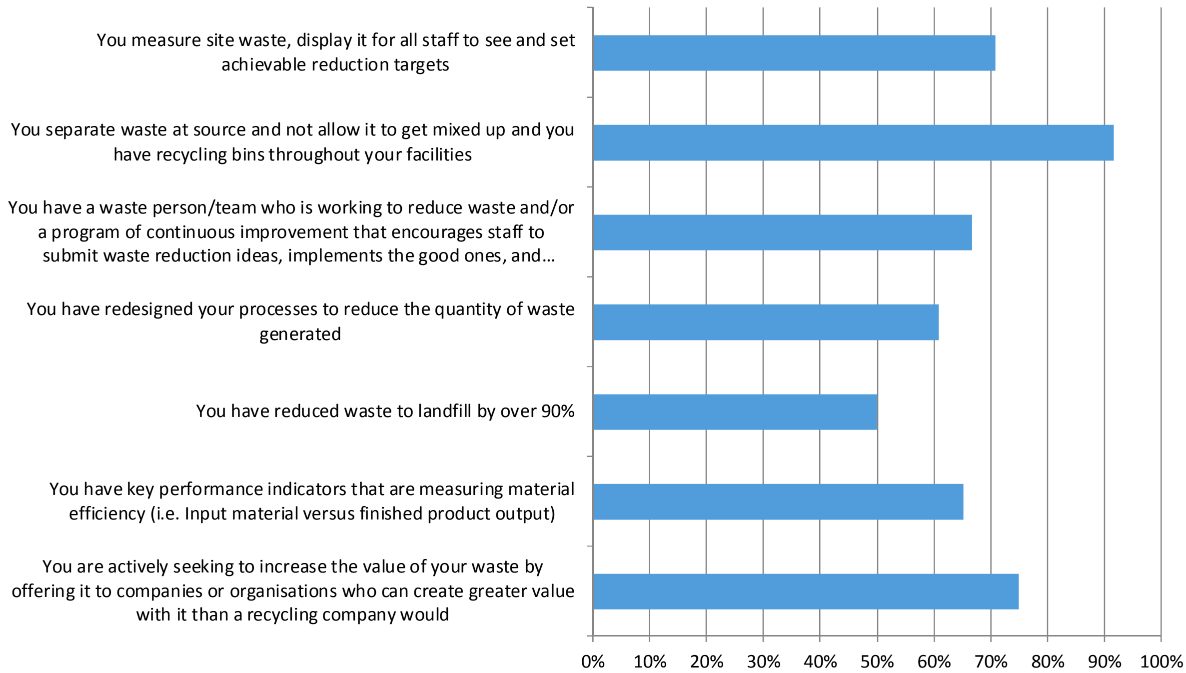
83 UK Department for Environment, Food and Rural Affairs, The Further Benefits of Business Resource Efficiency, 2011, DEFRA, p. 37.

84 EEF, Ascending the Waste Hierarchy: Practical Issues in Manufacturing, September 2011, p. 7.

85 See Appendix 3 for details of the survey.

86 Given the self-selection bias of survey respondents (who are more likely to have adopted resource productivity), this is likely to be a high estimate.

Figure 29: Results of Next Manufacturing Revolution Survey Questions Regarding Waste: Percentage of Respondents Agreeing with the Statements[87]



Reducing waste also has non-monetary benefits. Socially, for example, fewer disposal sites are needed. Environmentally, pollution and contamination risks reduce. For this study, the greenhouse gas emissions impact has been calculated comprising two components: (a) Avoided emissions because wasted product did not need to be created, and; (b) Avoided landfill emissions.

The combined greenhouse gas emissions benefit is **2.6 $MtCO_2e$** per year, with the majority of this coming from avoided food, drink and tobacco process waste due to its high embodied greenhouse gas emissions (refer to Appendix 6 for details of how this was calculated).

[87] Note that the survey only gave the response options of ‘yes’ and ‘no’.

Barriers to the Adoption of Process Waste Reduction and Recycling

There are four key barriers to achieving the full potential of process waste reduction and recycling of process waste[88,89], which are heavily interdependent:

1. **Senior executive leadership**. A commonly raised barrier to waste reduction is the lack of time/resources for line managers/staff to investigate waste saving opportunities, including finding markets for buyers. This is considered to result primarily from of a lack of prioritisation by senior executives who are unaware of the full value of waste improvement (see information point 2a below).

   Compare the substantial reduction in waste to landfill where high landfill prices and strong legislation combined with transparent volumes and costs has prompted executive action. Some commentators have suggested that this "strong emphasis on achieving 'zero waste to landfill' detracts from the more fundamental activity of waste prevention"[90].

   Senior executive involvement in waste is important not just to release resources, but also to change the culture of a company around an issue, set targets (linked to bonuses), and drive the behaviour of the organisation.

   The peer review of this study indicated that senior executive leadership is the most important barrier to be addressed, because once executives are aware of the opportunities, they can take steps to obtain the information and appropriately instruct the design process.

2. **Information**. There are several dimensions to the waste information barrier:

   a. Production waste is **difficult to measure** because some of it is recycled internally and the rest exits a production site in a range of ways. The most visible and easily measured waste is that which is transported to landfill because it is quantified and invoiced. The absence of data on the magnitude and therefore full cost /value of waste makes focussing on the issue difficult for companies.

   b. There is limited **market transparency** related to waste. This includes information on the value of by-products/waste types, market demand, potential buyers, location of buyers, opportunities to increase the value of waste streams, supply of waste (for incorporation into products), and the condition of this waste.

   c. Information on **how to reduce process waste** is limited. This includes knowledge of Incremental/Process & Systems/Structural Change/Core Redesign opportunities, as well as case studies of similar companies who have made substantial, profitable improvements.

[88] Recycling post-consumer is considered in the Circular Resource Use chapter.
[89] Sources include: World Economic Forum, Driving Sustainable Consumption: Value Chain Waste Overview Briefing, WEF, undated; Greater London Authority, Making Business Sense of Waste: The Mayor's Business Waste Strategy for London, GLA, 2011; Warhurst, M., Overcoming the Barriers: Policies to Create a Real Recycling Society, Friends of the Earth, undated; Defra, WR1403: Business Waste Prevention Evidence Review, Defra, 2011; Next Manufacturing Survey; Parliamentary Office of Science and Technology, Maximising the Value of Recycled Materials, Houses of Parliament, POSTNOTE 425, Jan 2013.
[90] For example, see Defra, WR1403: Business Waste Prevention Evidence Review, Defra, 2011.

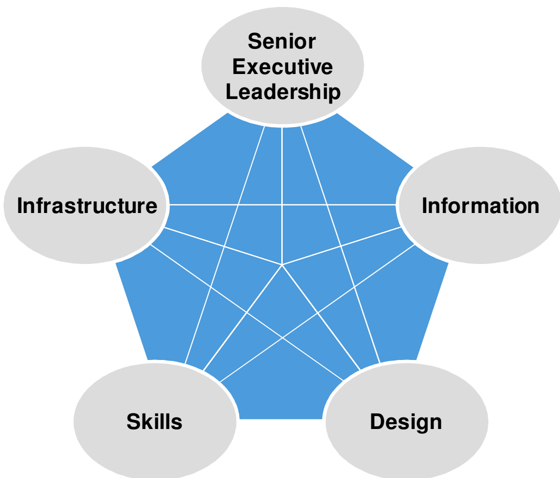
3. **Product Design**. Designers rarely develop products to incorporate waste material from other companies (or their own). Similarly, they rarely give regard to the choice and use of materials so that production waste (and end of life waste) can be easily recycled and/or fetch the highest sale price. These considerations are not part of conventional design processes. This is partly influenced by lack of information, partly by the training/skills of designers and also lack of senior executive attention/leadership on the issue.

4. **Skills**. The literature notes a lack of skilled personnel capable of driving waste reduction. Like energy efficiency, process waste reduction requires capabilities in engineering, commercial analysis, change management and systems thinking.

5. **Infrastructure**[91]. Waste management requires upfront investment in infrastructure. Local authorities make some of this investment, but the rest must be privately sourced. However, the attractiveness for private investment is limited firstly by an inconsistent supply and quality of recyclate, because of variation in recycling systems across England and the volumes of recyclate being exported. Secondly, there is a 'chicken and egg' problem: for a consistent supply to develop there must be a demand, but demand will not develop without a consistent supply. This is slowly being addressed, for example:
    - WRAP and the UK Green Investment Bank provide funding to help start up new recycling processes
    - Voluntary agreements between manufacturers and reprocessors, such as the Courtauld Commitment, can link up the stages of the recycling chain and help provide security for investors
    - The Courtauld Commitment helps manufacturers to increase recycling of their packaging as well as using more recycled material in new packaging. Corporate social responsibility commitments made by individual companies can have the same effect.

The strong inter-relatedness of these barriers means that they must all be addressed simultaneously if production waste is to be fully addressed. The absence of one provides reasons/excuses for inaction.

Figure 30: Process Waste Barrier Ecosystem



[91] The discussion of the infrastructure barrier repeats the concerns raised in POSTNOTE 425. Source: Parliamentary Office of Science and Technology, Maximising the Value of Recycled Materials, Houses of Parliament, POSTNOTE 425, Jan 2013.

Chapter 5: Packaging Optimisation

Chapter Summary

Packaging, including that used between companies and for customers, adds value to the manufacturing supply chain in a wide variety of ways including containing, protecting, transporting, labelling, displaying, marketing and preserving products. In doing so, packaging must serve the needs of multiple stakeholders along a value chain. Therefore changing packaging is a multi-purpose, multi-party optimisation exercise.

In 2010, UK manufacturers spent £10.8billion on packaging and the UK produced 10.8 million tonnes of end of life packaging. This total amount of end of life packaging has been increasing at approximately 1.5% p.a. for the last decade. Various pieces of legislation and voluntary agreements have been introduced that, directly and indirectly, have impacted packaging usage and driven an increase in recycling and recovery rates from 38% to 67% between 1999 and 2010. At the same time, packaging intensity (packaging per unit output) in UK manufacturing has improved by 10% (0.9% p.a.). The overall dynamic has therefore been one of improving domestic packaging intensity offset by increasing packaging from product imports, leading to a slow increase in packaging tonnes, but with significantly increased rates of recycling and recovery.

Good practice companies, both business to business (B2B) and business to consumer (B2C), have achieved far greater packaging improvement than the historical average improvement rate of 0.9% p.a. B2B companies such as Toyota and Atlas Copco have shown an ability to drive packaging reductions of 5% p.a. for five years or more by moving beyond a pure recycling focus to a broader set of solutions, including redesigning packaging to eliminate layers/components, light-weighting and new materials. Leading B2C companies such as L'Oreal and Adnams have achieved 30%+ packaging use reductions for individual products often in a short space of time through light-weighting of primary packaging. They have done this by working with multiple parties to understand all parties' requirements of the packaging and then reshaping, reducing and substituting the material used to fit the full set of requirements – using good design as well as emerging materials and fabrication technologies to create innovative solutions.

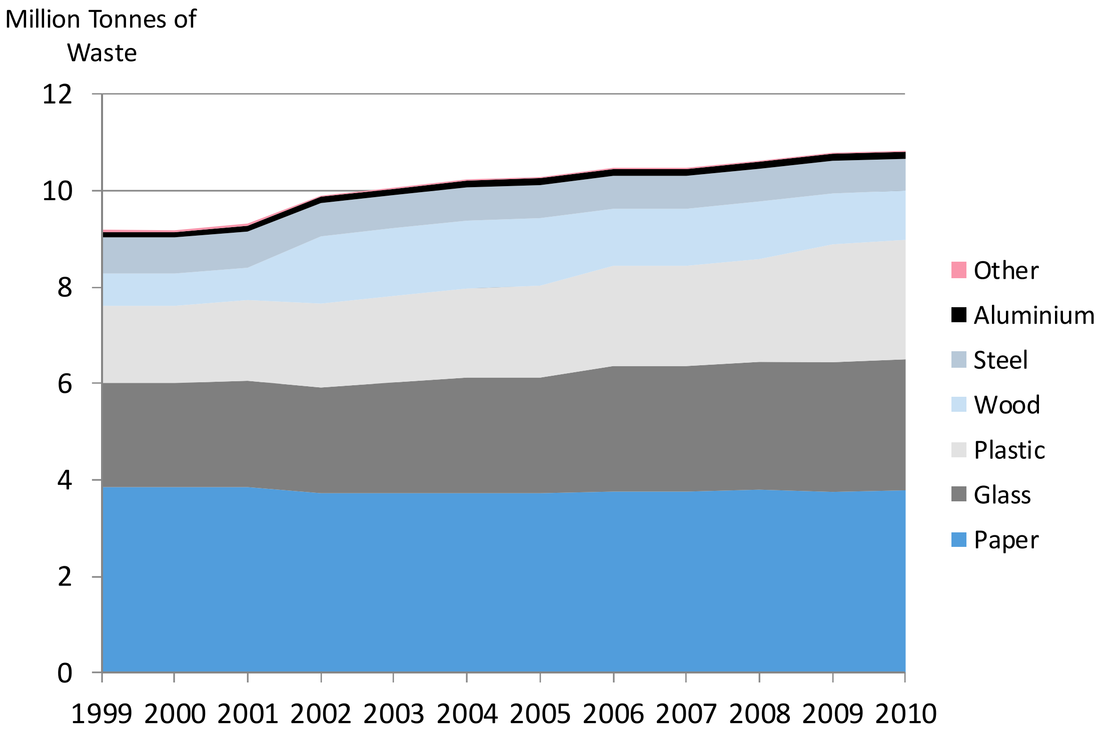
The potential opportunity from further optimising packaging is worth **£450 million p.a.** in cost savings, mostly in B2B packaging. This would also create environmental and social benefits including reduced greenhouse gas emissions through avoided embodied emissions in wasted product worth **0.55 MtCO$_2$e** per annum and lower emissions from transportation lighter packaging.

Five inter-related barriers exist to further substantial optimisation of packaging usage: senior executive leadership, information availability/clarity, design, resources and collaboration. All of these must be addressed simultaneously to unlock the benefits available.

UK Packaging Usage and Recycling Trends

In 2010 UK manufacturers spent £10.8 billion on packaging[92] – including for internal use, shipping between suppliers and primary and secondary packaging[93]. Overall end of life packaging in the UK has grown steadily over time, from 9.2 million tonnes in 1999 to 10.8 million tonnes in 2010. This represents an average tonnage growth rate of 1.5% p.a.[94] Figure 31 presents this trend.

Figure 31: Historical UK End of Life Packaging Generation by Type of Packaging, 1999-2010



Source: DEFRA, Waste and Recycling – Waste and Recovery from Packaging Statistics, 2008, updated with 2009 and 2010 data

Over this period, several key pieces of legislation have impacted packaging, including[95]:

- Rapidly increasing price of landfill disposal, driven by the escalating landfill tax introduced to assist the UK to achieve its obligations under the European Commission's Landfill Directive[96]. From 2012 onwards, landfill is the most expensive conventional disposal option in the UK.
- To encourage companies to reduce the waste they generate, the Waste (England and Wales) Regulations 2011 require any business that produces or handles waste to take all reasonable measures to apply the waste hierarchy[97].

[92] Calculated as UK manufactured packaging, plus packaging imports, less packaging exports; not including packaging associated with imported goods. Sources: ONS Index of Production; ONS Annual Business Survey, Sections C&D; ONS Divisional Estimates and Import/Export data from www.uktradeinfo.com.
[93] Primary packaging is the immediate packaging around the product; secondary packaging is packaging used to aggregate products for transportation.
[94] See DEFRA Statistics, 'Waste and Recycling – Recycling and Recovery from Packaging', 2008, updated with 2009 and 2010 data http://www.defra.gov.uk/evidence/statistics/environment/index.htm. Excluding wood (due to industry concerns on data accuracy) drops the average growth rate to 1.3%.
[95] See also the Process Waste chapter of this Next Manufacturing Revolution study.
[96] For more information about the Landfill Directive refer to Council Directive 1999/31/EC of 26 April 1999.

- The Packaging and Packaging Waste Directive 1994 set the framework for the Producer Responsibility Obligations (Packaging Waste) Regulations 2007 (as amended)[98]. These require businesses to recover and recycle end of life packaging to meet UK recovery and recycling targets, as part of EU targets. UK businesses who introduce packaging to the UK market are required to share the costs associated with reprocessing packaging, based on their position within the supply chain. This involves companies purchasing Packaging Recovery Notes (PRNs) (or PERNs for export packaging) – certificates that show that one tonne of packaging has been reprocessed[99].
- The Packaging (Essential Requirements) Regulations[100] specify that packaging volume and weight must be minimised whilst maintaining safety, hygiene and acceptability. Packaging must permit reuse or recovery and meet environmental standards.

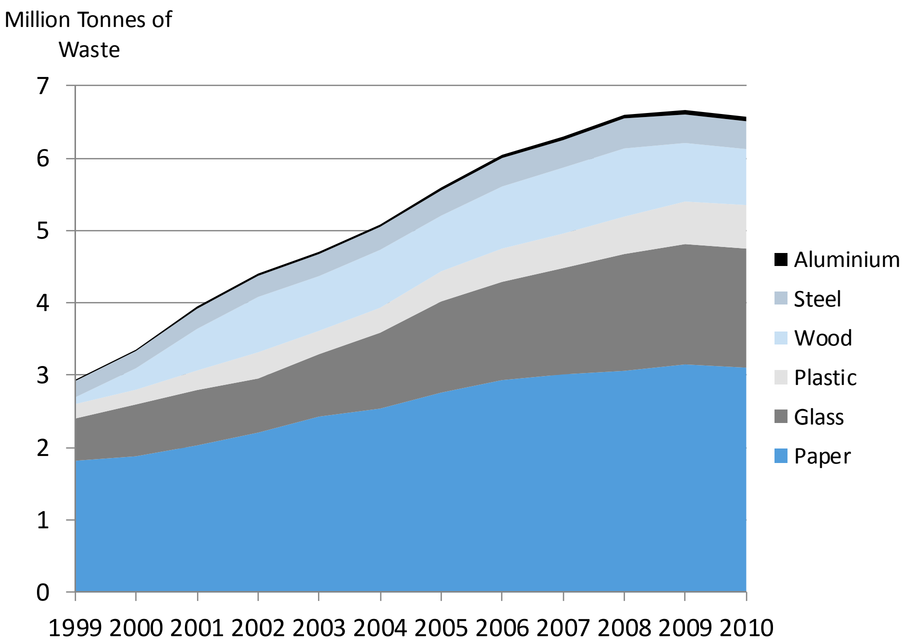
Various voluntary agreements also exist. For example, the Courtauld Commitment developed in 2005 (with a second phase in 2010 and third phase in 2013) is working to reduce food and packaging waste in the grocery supply chain[101]. The Industry Council for Packaging and the Environment also promote a Responsible Packaging Code of Practice[102], which builds on the above regulations.

The most visible and substantial shift as a result of these regulations and efforts has been a significant increase in the overall rate of packaging recycling from all sources – industrial, commercial and household. DEFRA figures indicate that the amount of UK packaging waste that is recycled has more than doubled from 3.1 million tonnes in 1999 (a recycling rate of 33.6%) to 6.6 million tonnes in 2010 (a 60.7% recycling rate)[103]. Figure 32 presents this trend.

---

[97] The waste hierarchy as defined by the EU Waste Framework Directive and used by Defra, the Waste and Resources Action Program (WRAP) and others is: Prevention (avoid & reduce), Re-use, Recycle, Recover, Dispose.
[98] For more information about the Producer Responsibility Obligations (packaging waste) refer to http://www.defra.gov.uk/environment/waste/business/packaging-producer/
[99] A PRN is issued by accredited re-processors once they have recovered and recycled each tonne of packaging waste.
[100] See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/142445/bis-11-525-packaging-regulations-quick-start.pdf for details.
[101] See http://www.wrap.org.uk/category/initiatives/courtauld-commitment for details.
[102] See http://www.incpen.org/docs/CodeofPractice.pdf for further information.
[103] See DEFRA Statistics, 'Waste and Recycling – Recycling and Recovery from Packaging', 2008, updated with 2009 and 2010 data http://www.defra.gov.uk/evidence/statistics/environment/index.htm.

Figure 32: Historical UK Packaging Waste Recycling by Type of Packaging, 1999-2010



Source: DEFRA, Waste and Recycling – Waste and Recovery from Packaging Statistics, 2008, updated with 2009 and 2010 data

In addition, several hundred thousand tonnes of packaging are 'recovered' via waste-to-energy facilities (496kt in 1999, rising to 722kt in 2010). Thus, the combined recycling and recovery rate for end of life packaging has increased from 38% in 1999 to 67% in 2010[104].

UK Packaging Intensity Trends

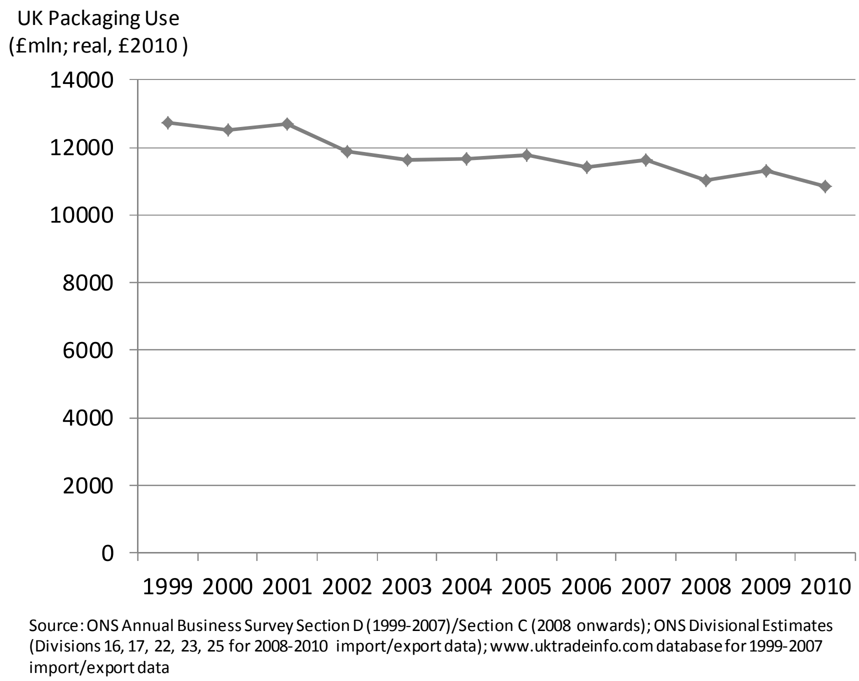
The UK end of life packaging stream includes both packaging generated and used by the UK manufacturing sector as well as packaging associated with imported goods. The Packaging Federation estimates that 25% to 30% of packaging arises from this import stream[105].

From 1999 to 2010, packaging used by UK manufacturers (i.e. excluding packaging associated with imported goods) fell in real terms by 15% (1.4% p.a. on average). This is shown in Figure 33.

[104] See DEFRA Statistics, 'Waste and Recycling – Recycling and Recovery from Packaging', 2008, updated with 2009 and 2010 data http://www.defra.gov.uk/evidence/statistics/environment/index.htm.

[105] See The Packaging Federation, UK Market Report no. 5, 2006, amongst others.

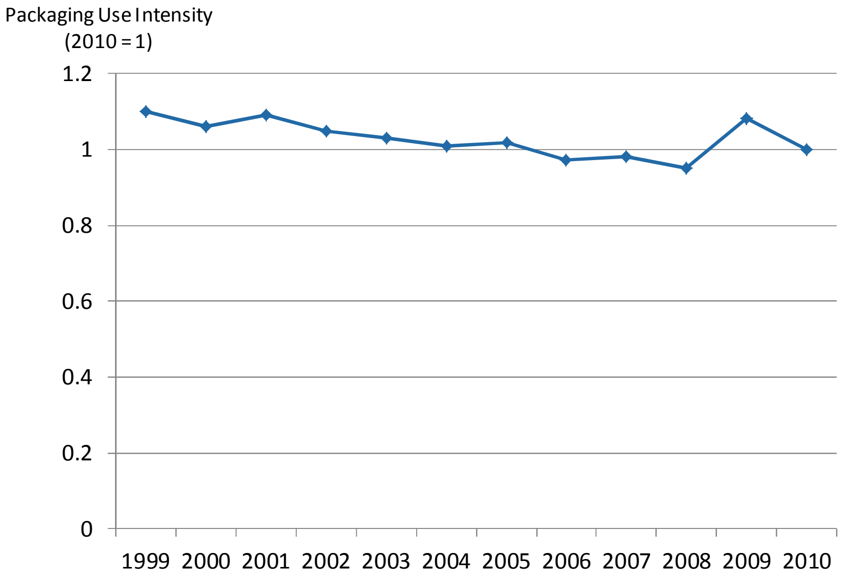
Figure 33: UK Manufacturing Net Packaging Use[106,107] , 1999-2010



However, over the same time period, UK manufacturing output also fell[108]. Dividing UK manufacturing net packaging use by production output allows us to understand manufacturers' packaging intensity (see Figure 34). Overall, UK manufacturers have become approximately 10% less packaging intensive from 1999 to 2010. This represents an annual rate of improvement of 0.9% p.a.[109]

[106] Calculated from UK packaging production, less exported packaging, plus imported packaging, but excluding packaging linked to imported goods.
[107] Sources include ONS Annual Business Survey, Section D (1999-2007)/Section C (2008 onwards); ONS Divisional Estimates (Divisions 16, 17, 22, 23, 25 for 2008-2010 import/export data) and www.uktradeinfo.com database for 1999-2007 import/export data.
[108] The ONS Index of Production fell from 110.5 in 1999 to 103.8 in 2010.
[109] We note that this could be due to a number of reasons, including industry mix – this requires further investigation.

Figure 34: UK Manufacturing Packaging Use Intensity[110] *, 1999-2010*



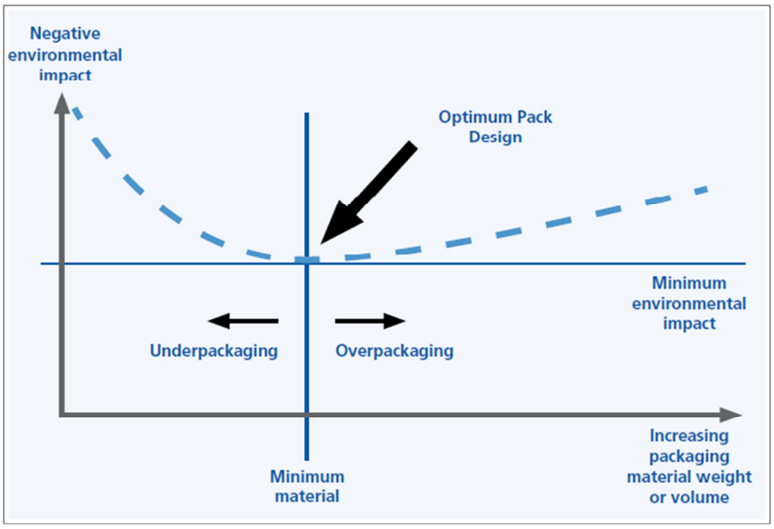
Source: ONS Annual Business Survey Section D (1999-2007)/Section C (2008 onwards); ONS Divisional Estimates (Divisions 16, 17, 22, 23, 25 for 2008-2010 import/export data); www.uktradeinfo.com database for 1999-2007 import/export data; ONS – Index of Production (1999-2010)

This steady improvement requires a balance between packaging weight and product protection – too much packaging and the packaging itself has an unnecessarily high environmental impact; too little packaging and products can be damaged. Figure 35 shows this optimum packaging curve. Note that the minimum material point decreases with time as new materials, packaging technologies, design sophistication[111] and packaging manufacturing techniques improve.

[110] Sources include ONS Index of Production (1999-2010); ONS Annual Business Survey, Section D (1999-2007)/Section C (2008 onwards); ONS Divisional Estimates (Divisions 16, 17, 22, 23, 25 for 2008-2010 import/export data) and www.uktradeinfo.com database for 1999-2007 import/export data.

[111] For example, the use of finite element analysis to optimise material use for strength.

Figure 35: Optimum Packaging Curve[112]



Source: Innventia AB model, from 'Packaging in the Sustainability Agenda – A Guide for Corporate Decision Makers', ECR Europe 2009 based on data from 'Towards Greener Households' (2004) by Dr J. Kooijman for INCPEN

In summary, UK manufacturing production has decreased over time, while packaging intensity has steadily improved. The slow increase in overall end of life packaging is therefore largely a result of increased product imports. At the same time, the UK has increased recycling rates and recovery of end of life packaging.

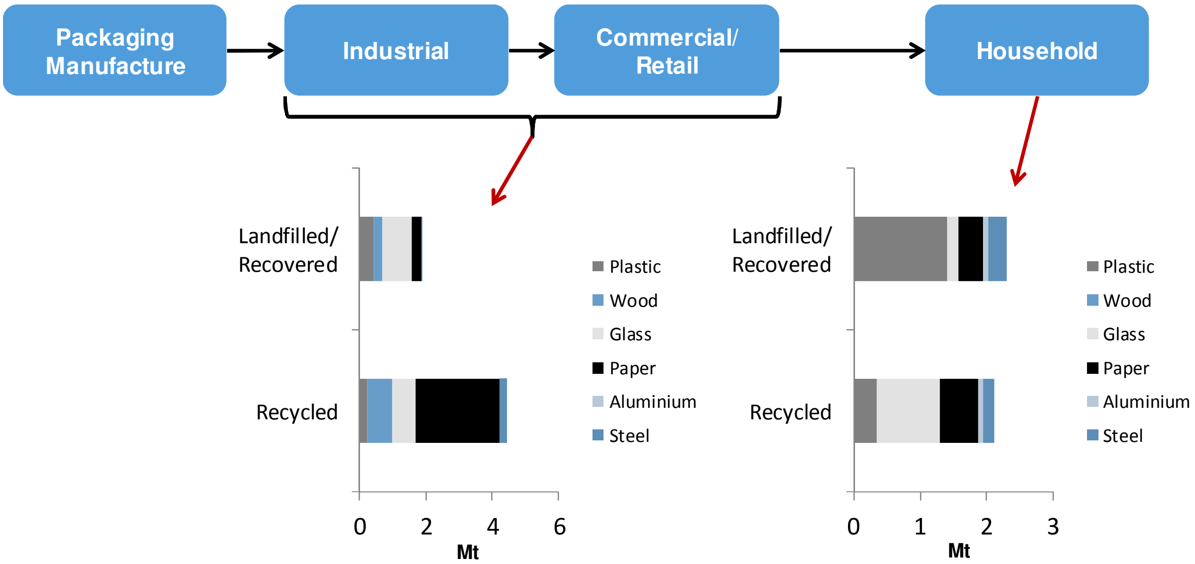
The waste hierarchy[113] of Prevention (avoid & reduce), Re-use, Recycle, Recover and Dispose is a cascade of options to capture value from products beyond their initial usage with value decreasing at lower positions in the cascade. Recycling and recovery, which have been a focus in the UK for the last decade, are lower value options. This means that we are in effect recycling volume rather than creating greatest value. Greater value may exist for many sub-sectors in optimising the overall level of packaging (e.g. through continued light-weighting optimisation and use of latest packaging technologies/designs), reuse and cascaded use for certain types of packaging and through the use of new materials. These opportunities are explored in the following sections.

[112] Innventia AB model, from 'Packaging in the Sustainability Agenda – A Guide for Corporate Decision Makers', ECR Europe, 2009 based on data in 'Towards Greener Households' (2004) by Dr J. Kooijman for INCPEN.
[113] Defined by the EU Waste Framework Directive and used by Defra, the Waste and Resources Action Program (WRAP) and others.

Company/Best Practice Packaging Usage Performance

Packaging is used in all sectors and becomes 'end of life' at various points in the product lifecycle. Based on available data[114] it is estimated that 6.3 million tonnes (58%) of packaging becomes waste from industrial and commercial activities, with 4.5 million tonnes (42%) being household packaging waste[115]. Figure 36 presents the breakdown of these figures by packaging type and between the packaging which is recycled and that which is sent to landfill or otherwise recovered.

Figure 36: Estimated Breakdown of UK End of Life Packaging Source (C&I vs Household)



Note: Approximately 14% of household waste is treated for energy recovery
Source: DEFRA, Waste and Recycling – Waste and Recovery from Packaging, 2008 updated with 2009 and 2010 data; WRAP Plastic Market Situation Report 2010; WRAP Wood Market Situation Report 2010; WRAP Glass Market Situation Report 2008; DEFRA, WasteDataFlow 2006-2010; StatsWales 2006-2010 data; SEPA 2006-2010 data; NIEA 2006-2010 data; 2012 Packflow report

From these figures it is clear that UK businesses already have a focus on recycling; the overall industrial/commercial recycling rate is approximately 70%, 10% higher than the overall UK packaging recycling rate.

A large proportion of commercial/retail waste is FMCG/food & drink related (overall, the grocery sector is estimated to account for 70% of packaging usage, through the whole value chain[116]) and packaging serves a range of different functions for B2C products. Therefore business to business (B2B) and business to consumer (B2C) packaging are considered separately below.

[114] Sources include : DEFRA, Waste and Recycling – Waste and Recovery from Packaging, 2008 updated with 2009 and 2010 data; WRAP Plastic Market Situation Report 2010; WRAP Wood Market Situation Report 2010; WRAP Glass Market Situation Report 2008; DEFRA, WasteDataFlow 2006-2010; StatsWales 2006-2010 data; SEPA 2006-2010 data; NIEA 2006-2010 data; 2012 Packflow report.

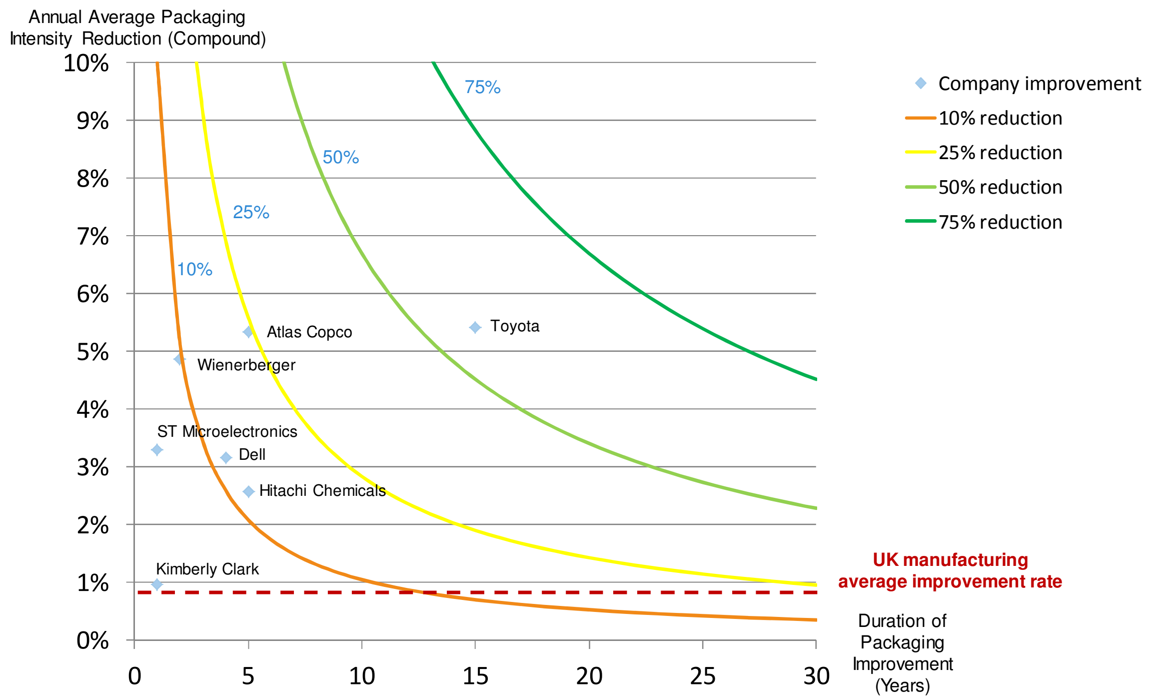
[115] The available data is insufficiently detailed to enable break down of the non-household figures between industry and commercial/retail activities.

[116] See http://www.wrap.org.uk/content/resource-efficiency-grocery-sector.

B2B businesses:

Figure 37 presents the rate of improvement and duration of packaging intensity improvement for a range of (mainly) blue chip B2B companies.

Figure 37: Good Practice Company Packaging Intensity[117] Reduction Examples



Note: Un-named datapoints are companies who provided data confidentially or are not named for other reasons; all named companies are plotted based on publicly available information.
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review

This data shows a wide variation of packaging intensity improvement rates within and across sectors, with many companies performing well above the UK average rate of improvement of 0.9% p.a. discussed above.

Several companies, across a range of manufacturing sub-sectors, are making significant inroads into their packaging weight including Dell and ST Microelectronics in electrical and electronic products, Hitachi Chemicals in chemicals, Wienerberger in mineral products, Toyota in vehicles and Atlas Copco in machinery. Best practice companies with comprehensive improvement programs are achieving a 5% p.a. packaging intensity reduction rate, well above the 0.9% p.a. average improvement rate. Toyota has achieved a 57% reduction in packaging weight per vehicle over 15 years (a CAGR of 5.4% p.a.), whilst Atlas Copco have achieved a 24% reduction in packaging intensity in only five years (a CAGR of 5.3% p.a.).

B2C Businesses:

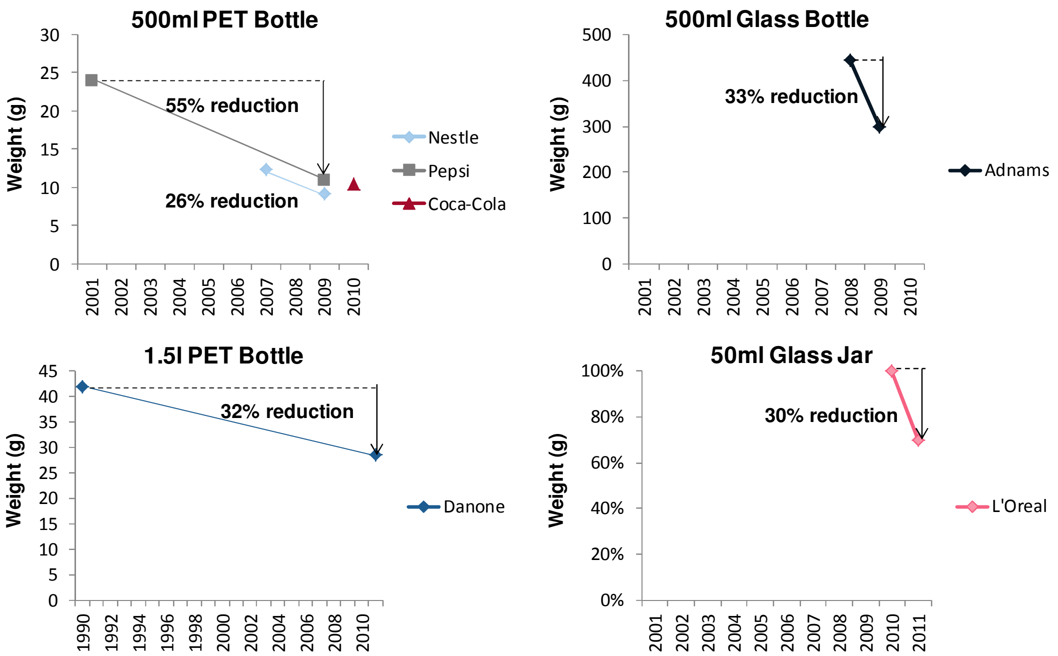
FMCG companies have also pursued wide-ranging packaging optimisation programs including removal/reduction of packaging (e.g. Coke removing cardboard under slabs of cans; Ecover and others selling concentrated detergents; direct printing to avoid extra labels), use of new materials/technologies (e.g. switching from bottles/cans to film pouches for size and weight reduction for soups and sauces; use of plastic multi-can carriers to avoid cardboard boxes) and

[117] Packaging intensity defined as weight of packaging per unit of product.

development of re-useable packaging (e.g. Puma's shoe bag, rather than box; re-usable transit packaging for home delivery).

One area of focus has been light-weighting of primary product packaging. For example, 400g metal food cans have reduced in weight from 90g to 55g over the last 40 years, and 330ml metal drinks cans from 21g to 15g over 30 years[118]. Figure 38 shows additional examples for PET and glass packaging - achievements of 30% weight reduction are not unusual across various types of packaging, sometimes in a very short space of time.

Figure 38: PET/Glass Packaging Light-weighting Examples



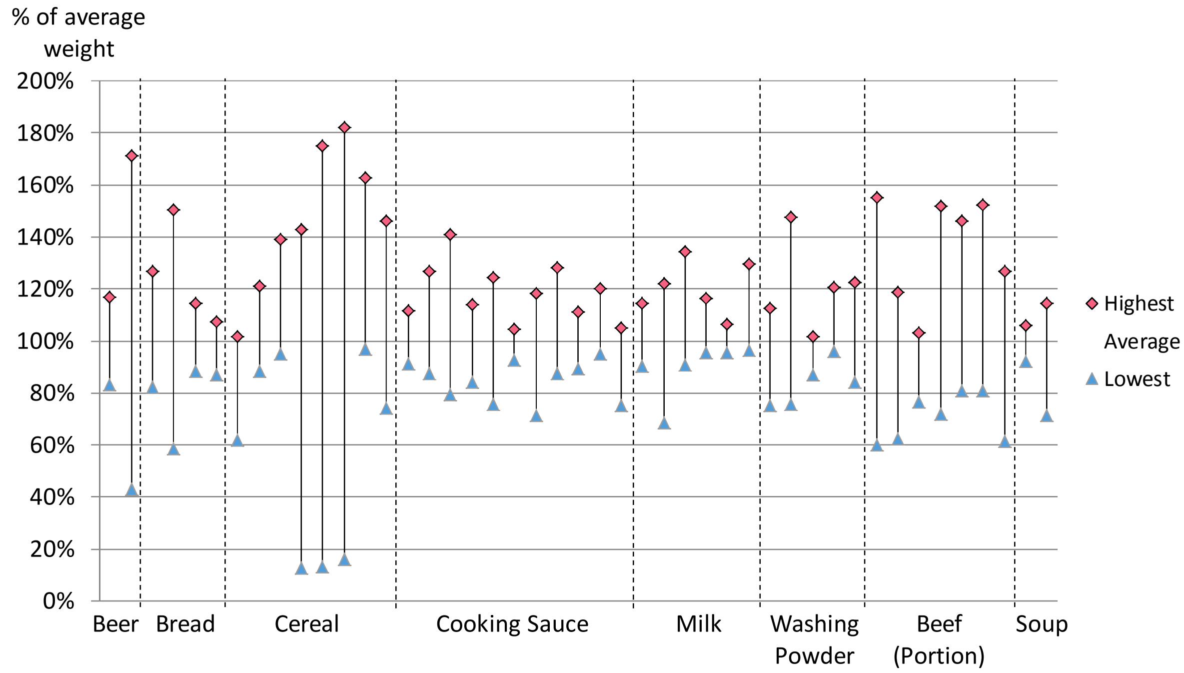
Sources: Danone 2011 Sustainability Report; Doughty Hanson, Private Equity and Responsible Investment: An Opportunity for Value Creation, 2011; 2011 L'Oreal GRI Datasheets; 2010-11 TCCC Sustainability Report, http://www.pepsico.com/Purpose/Environmental-Sustainability ; http://www.nestle.com/csv/Nestle/ourperformance/DataSummary/Pages/DataSummary.aspx; 2011 Creating Shared Value report; http://www.nestle-waters.com/environment/bottled-water-packaging/Pages/eco-shape-pet-bottle.aspx ; Next Manufacturing Revolution Analysis

Weight reduction has also been pursued in secondary packaging. For example, the average weight of paper used in corrugated board packaging has declined by approximately 10% over the last 10 years from 533 to 482 g/m^2 [119]. Design optimisation has also delivered other savings, for example through better pallet utilisation.

Historical data within WRAP's UK Packaging Benchmark database[120] suggests that this weight reduction is not unusual - 'lightest in class' items for FMCG packaging are often substantially lower in weight than 'average in class' packaging, across many different grocery categories (e.g. bakery, cereals, drinks). Figure 39 shows the range of differences (average vs. lowest weight) across selected categories – the range covers various individual pack types (stock keeping units) within each category.

[118] See http://www.incpen.org/docs/PackagingReduction.pdf for further details.
[119] Data provided by CPI.
[120] See http://www.wrap.org.uk/content/uk-packaging-benchmark-database, a database focused on the grocery sector, providing best-practice, average and worst-practice data by grocery sector. Best-in-class weights are an approximate guide that do not take account of trade-offs between sales and transport packaging or the variety of supply chains.

Figure 39: Packaging Weight Variance Around Average (100%) for Selected UK Grocery Categories and Sub-Categories



Note: Each line represents a certain weight/volume class within each grocery sub-category
Average = 100%
Source: WRAP UK Packaging Benchmark Database

Case study examples for a range of manufacturing sub-sectors are presented on the Next Manufacturing Revolution website www.nextmanufacturingrevolution.org on the 'Case Studies' tab.

How Good Practice Companies Optimise their Packaging Usage

Optimising packaging is a multi-purpose, multi-party exercise. Packaging plays a large number of vital roles, including containing, protecting, transporting, labelling, displaying, marketing, and preserving products – these functional roles need to be balanced with the benefits from any redesign. In addition, there are multiple stakeholders along the value chain who have requirements for how products should best be packaged (to achieve varying objectives) including packaging convertors, manufacturers, warehouses, distributors, retailers and waste management companies.

Good practice companies have focussed on four types of improvement opportunities, each differing in ease of implementation and investment requirement, to optimise their packaging usage and impact on the environment, while improving profitability. All four types of opportunity can impact all levels of the waste hierarchy.

1. **Incremental**. These opportunities typically involve behaviour change, such as measuring packaging usage, displaying it for all staff to see and setting achievable reduction targets and KPIs. In addition, where easily substitutable materials are available at limited additional cost, but which have lower environmental impact, these have been used (e.g. using FSC-certified material, increasing recycled content). Often these incremental opportunities are referred to as 'quick wins' because they can be implemented quickly, involve limited capital expenditure, and frequently create tangible benefits – albeit these are mostly smaller than for the other types of improvement actions.

For example, incremental improvements include substituting biodegradable materials for existing packaging materials, where they are a drop–in replacement, to limit the impact on landfill and return nutrients to the soil[121].

2. **Processes and Systems**. Packaging improvements that involve changes in processes fall into this category, such as establishing a packaging improvement program/team, or implementing stated policies around reducing, reusing and recycling packaging. Many of these savings are inexpensive in capital terms, but can result in larger benefits than the 'quick wins' above. While they can take longer to implement than Incremental adjustments, Process and Systems changes are more likely to result in sustained improvement.

   For example, good practice companies try to extract value, wherever possible, from materials used. One major company recently identified an opportunity to re-use inbound PET packaging material for their filled outbound (non-food) goods. Where packaging materials cannot be re-used directly within a company, companies can identify external sources of value. Many companies already sell cardboard packaging to a merchant for re-use elsewhere, to be made into filler for packaging downstream, or to recycling companies, where the recycler will pay for good quality fibre.

   Another example of a process and system change is the elimination of unnecessary layers or components of packaging.

3. **Structural Change**. These opportunities typically involve working with packaging convertors (and retailers in FMCG) to redesign packaging for reduced material usage, redesign products to optimise the packaging required, or to incorporate the latest packaging materials and design techniques. The cost associated with such opportunities is typically more substantial, either due to capital investment required in changing machinery/new tooling, or increased cost associated with designers' time and testing. For new products the additional design cost can be small but lead to substantially lower lifetime packaging and production costs.

   Example structural optimisation opportunities related to packaging in the manufacturing sector include:
   - Redesigning packaging for 'light-weighting'. For example, in corrugated packaging, lighter weight papers and thinner fluting results in less packaging thickness and volume, enabling more packaging per pallet, lower pallet heights, better vehicle utilization of load space and potentially fewer vehicle trips
   - Product/packaging redesign for more optimal packing configurations
   - Ensuring that packaging is designed appropriately for recyclability, where appropriate (e.g. avoiding mixed media and mixed plastics)
   - Shifting from rigid to flexible packaging (e.g. pouches replacing bottles/cans for soups, sauces; e.g. trans-shipping in large flexible bags instead of barrels or boxes)
   - Creating refill packs to allow customers to re-use existing packaging (e.g. done by some herb manufacturers to refill glass jars; as used to occur for some laundry products to allow customers to reuse trigger mechanisms).

[121] Note that where alternative materials require packaging redesign (i.e. the alternative materials are not drop-in replacements) this is a Structural change.

4. **Core Redesign**. The above opportunities can be extended by working together with suppliers and customers to fundamentally redesign/optimise the packaging flow along the value chain between factories/warehouses and commercial/retail or to eliminate packaging altogether (or reduce by a substantial amount).

   For example, various core redesign opportunities for packaging have been adopted by pioneering manufacturers:
   - Reusing packaging at intermediate steps of the value chain: automotive OEMs obtain kits of parts from their suppliers in re-usable trays which are then sent back to the supplier to use again. Retailers currently do this for fruit and vegetables, but not for most other grocery categories[122, 123].
   - Reusing packaging at the end-of-life stage of the value chain: soft drinks companies often have reusable glass bottles for on-trade channel (e.g. bars, restaurants). On-trade beer barrels are re-used many times (and are high value, so are tracked carefully). Some beverage companies and brewers are exploring this option to re-use bottles[124] recognising that infrastructure, cleaning and other costs need to be taken into account. Note that when reusing packaging the initial cost/resource usage increases, but it is lower over the bottle's life-cycle as packaging is re-used.
   - Concentrating product. In Australia, for example, the major retailers require all laundry powder that they sell to be in concentrated form – reducing packaging as well as display space, warehouse space, product freight transport costs and effort/transport for consumers.

Incremental and Process & Systems changes are often easier to achieve as they involve fewer stakeholders, but generally lead to smaller benefits. Structural and Core Redesign opportunities can deliver substantial improvement, but require stakeholders along the whole value chain (packaging convertors, manufacturers/fillers, retailers and waste management companies) to work together to deliver innovations and new designs.

The rate of 0.9% p.a. packaging intensity improvement observed in the UK suggests that Incremental and Processes & Systems changes have been the focus for UK manufacturers to date. One-off examples of rapid substantial improvements in packaging intensity have involved Structural optimisation and Core Redesign. This suggests that further optimisation opportunities exist in Structural optimisation and Core Redesign.

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[122] Notable exceptions include reusable plastic grids/cases for holding soft drink bottles as well as Omega bakery baskets (see the Circular Resource Use chapter)

[123] Shelf Ready Packaging (SRP) in in the UK in 2011 is estimated to have cost US$1.87 billion and used 0.93 million tonnes of material. This is based on the 2011 global estimate of the cost of SRP of US$54billion, using 27million tonnes of material. This was pro-rated for the UK based on GDP (considered a conservative approach given that many of the world's nations do not widely use SRP). Sources: Smithers Pira, The Future of Retail Ready Packaging to 2017, 29 Oct 2012, https://www.smitherspira.com/future-of-retail-ready-packaging-to-2017.aspx [accessed 2 Jun 2013]; United Nations GDP figures for 2011: global GDP=US$70.202 trillion, UK GDP=US$2.429 trillion. Sourced from http://en.wikipedia.org/wiki/List_of_countries_by_GDP_(nominal) [accessed 2 Jun 2013].

[124] See Ellen MacArthur Foundation, Towards the Circular Economy, Volume 2 (2013), p68 for an example case study.

The Full Potential of Packaging Optimisation for UK Manufacturing

Of the £10.8 billion that UK manufacturers[125] spent on packaging in 2010[126], it is estimated that there is an additional (beyond what is covered in other chapters) savings potential for manufacturers of **£450million p.a.** from a range of opportunities – a 4% saving.

These opportunities apply to UK manufacturing as a whole (including both packaging convertors and manufacturers/fillers) and require the value chain to work together to achieve them. Since packaging companies are material convertors and solution providers, saving packaging material in many cases need not result in lower revenues or profits – more innovative, lighter weight packaging solutions may cost the same to manufacturers but save on resource usage, transport costs and environmental impacts. Similarly, a reusable container may cost more up front but then be reused many times.

Opportunities for further packaging optimisation include:

- **Further recycling.** There is headroom to increase the rate of recycling further, particularly for plastics, and there are several initiatives underway to do this[127]. However, increasing the rate of recycling of industrial packaging would add only a small amount of value to UK manufacturing sector. This value is already included in the Process Waste chapter of this study and is therefore not included here as a benefit of packaging optimisation, to avoid double counting.

- **Additional packaging optimisation in the FMCG sector**: The latest Courtauld 3 Commitment focus is on overall optimisation of food and packaging waste; a shift from pure packaging reduction in earlier phases. Courtauld 3 includes the target for 2015 of a 3% reduction in B2C packaging waste, worth £150mln at values indicated in the recent announcement[128]. This is equivalent to a 1.5% p.a. reduction; 0.6% ahead of the historical improvement rate in UK packaging intensity of 0.9% p.a. (and hence worth **£30mln p.a.** over and above historical improvement rates). To be conservative, and recognising that many FMCG packaging innovations will result in no direct packaging cost saving to the manufacturer, this figure is assumed as the packaging improvement opportunity for B2C products.

- **Brand value**: A number of FMCG companies have created brand/marketing value from optimising their packaging (including Coca Cola and Puma). They have recognised that this 'green' marketing benefit exceeds the 'look and feel' brand benefits of having a weightier container. It is possible that many more FMCG companies will recognise this benefit and drive improvements well beyond the Courtauld Commitment targets. This has not been quantified here due to the complexity of estimating take-up rates and the value of brand equity.

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[125] i.e. UK manufactured packaging, plus packaging imports, less packaging exports; not including packaging associated with imported goods.

[126] Sources: ONS Index of Production; ONS Annual Business Survey, Sections C&D; ONS Divisional Estimates and Import/Export data from www.uktradeinfo.com.

[127] Note: this study focuses on the UK manufacturing sector. There are larger value creation opportunities for the economy as a whole in increasing recycling rates (e.g. in the recycling /reprocessing industry). For example, the Ellen MacArthur Foundation report 'Towards the Circular Economy: Volume 2' highlights that 28,000 jobs have been created in France in packaging collection and sorting in the last 20 years.

[128] See http://www.wrap.org.uk/content/courtauld-commitment-3 for further details.

- **Increasing implementation of structured packaging programs in B2B companies:** Leading B2B companies are achieving substantial packaging usage reductions of 25% or more in total, at a rate of 5% p.a., with a comprehensive program addressing the areas of Incremental Improvements, Process & Systems Adjustment, Structural Change and Core Redesign. Achieving these rates of improvement represents a net annual 4.1% uplift on the underlying background rate of change of 0.9% p.a. Applying this uplift to the B2B element of the UK packaging market and capping improvements after five years suggests a potential value of **£425million p.a.**[129] once savings are fully achieved. This saving recognises that substantial material savings are available and therefore savings are expected to accrue to manufacturers.

- **Transport savings:** The good practice examples presented above show significant (30% and more) packaging material weight reduction opportunities within the FMCG sector. This was also found in a 2009 report by DEFRA[130], which highlights the opportunities available from optimising packaging and increasing recycling rates for end of life packaging. It includes work by DHL & WRAP showing improvement potential through light-weighting within the FMCG sector of 24% to 52%, depending on product category. The value of this saving for manufacturers is included in the Transport Efficiency chapter of this study, so is not counted here to avoid double counting.

The sum of these additional savings beyond what has been counted in other chapters represents 4% of the total £10.8billion spent on packaging in the UK in 2010. As could therefore be expected[131], this is smaller than the opportunity estimated in a WRAP/Food & Drink Federation report which identified general packaging cost improvement opportunities of 14% in surveyed plants[132]. Interestingly, the opportunities identified in this report appear to be mostly in the Incremental and Process & Systems categories of the framework discussed above and therefore represent only a proportion of the total opportunity available from more holistic redesign.

Next Manufacturing Revolution survey results (see Figure 40) show that most aspects of packaging good practice examined are only being done by 30% to 60% of respondents to date. Interestingly, only 30% of respondents indicated that they measured overall packaging usage and disseminated this information widely, suggesting that most respondents devolve responsibility to a specific individual or team. Overall, this indicates that substantial benefits remain untapped, especially since the survey likely includes a self-selection bias that meant respondents had a higher sustainability performance than industry average.

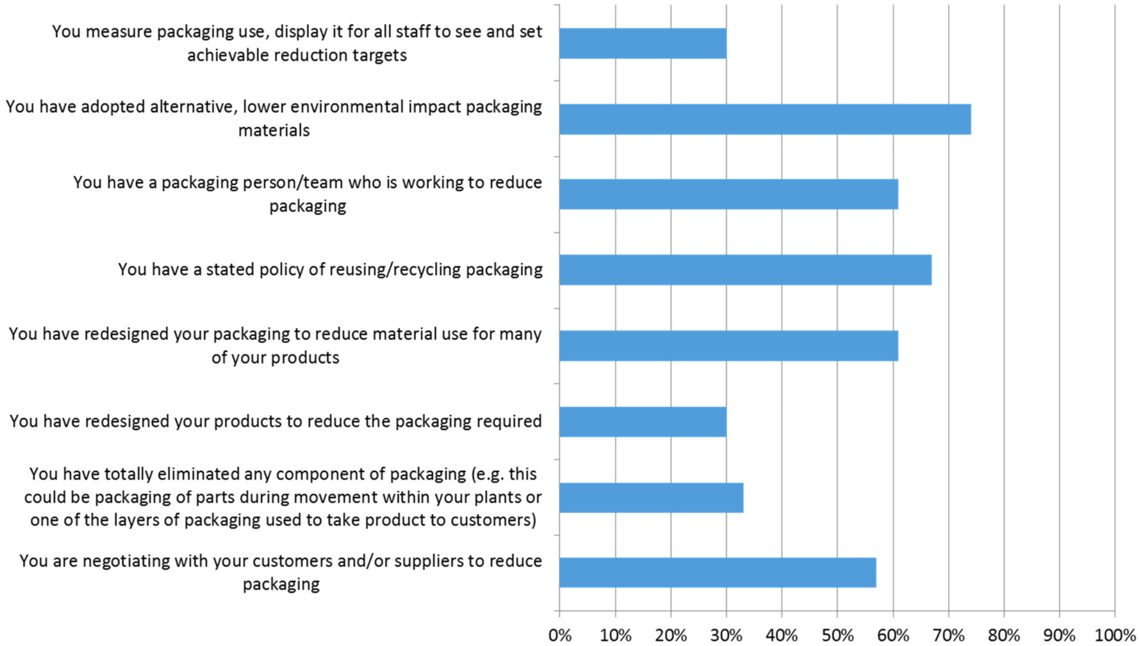
[129] 2010 UK packaging market estimated at £10.8bn; B2B sectors are ~30% of packaging usage (30% of £10.8bn = ~£3.25bn); 4% saving = ~£130m; cumulative saving after 5 years = 5x130 = ~£650m. Packaging convertors are UK manufacturers, so net saving is cost of goods sold (COGS) for packaging convertors. COGS ranges from ~54-76% for major quoted packaging convertors – a mid-point of 65% gives an estimated potential of £420-430m (65% x £650m).

[130] DEFRA, Making the most of Packaging – A strategy for a low-carbon economy, June 2009.

[131] Because the estimated saving in this chapter is only the additional benefit to the packaging savings already counted in other chapters.

[132] See WRAP, 'Opportunities for Resource Efficiency in the Food and Drink Sector', June 2011.

Figure 40: Results of Next Manufacturing Revolution Survey Questions Regarding Packaging: Percentage of Respondents Agreeing with the Statements[133]



Reducing packaging usage/waste has substantial non-monetary benefits. Socially, for example, fewer disposal sites are needed and less packaging ends up as litter. Environmentally, pollution and contamination risks reduce. The impact on greenhouse gas emissions comprises two main components: (a) avoided embodied emissions because packaging material did not need to be created; (b) avoided transport emissions through lighter weight of material.

The first of these is estimated to save greenhouse gas emissions of **0.55 $MtCO_2e$** p.a.[134] Transportation greenhouse gas emissions savings are included in the transport efficiency chapter.

Barriers to Optimising Packaging

Barriers to addressing packaging sit within the context of packaging optimisation being a complex challenge, involving multiple stakeholders. Packaging requirements can include parameters set by the manufacturer/filler and/or retailer, as well as being influenced by warehousing and distribution and end of life requirements from waste management companies. Innovation opportunities can arise from these stakeholders, as well as packaging convertors. These opportunities all need to be optimised within the UK regulatory framework and emerging sustainable packaging thinking. Achieving optimal solutions in such a value chain requires excellent information sharing and aligned thinking.

133 Refer to Appendix 3 for more details on the Next Manufacturing Revolution survey.
134 Overall 8% reduction (combined B2B and B2C reduction) in packaging used by UK manufacturers (excluding packaging associated with imported goods). Uniform 8% weight reduction applied to all types of packaging and recycling routes and multiplied by factors from DEFRA GHG Conversion Factors for Company Reporting, 2012.

This study identified five key barriers to achieving the full potential of optimised packaging and recycling of end of life packaging[135], which are interdependent:

1. **Senior Executive Leadership:** While senior executives (especially in B2C businesses) are aware of the regulatory requirements and consumer pressures to further optimise packaging, the complex nature of the optimisation challenge means that ongoing senior executive leadership is required. This is because only senior executives can:
    a. Marshal internal functions, supply chain and packaging suppliers to work together towards more optimal solutions.
    b. Make trade-offs around packaging, for example between packaging weight and marketing 'look and feel'. Such trade-offs can often only be resolved by senior executive decisions.
    c. Commit the necessary expenditure and resources to the redesign/solution development.

2. **Information**. There are several dimensions to the packaging information barrier:

    a. Packaging requirements are **complex**. Although all packaging passes through the manufacturing process, it becomes end of life at various points in the value chain (industry, commercial/retail, household). Requirements from packaging vary by value chain step and need to be clearly articulated and shared.
    b. There is a strong **emphasis on recycling**. Many reports[136] discuss both packaging optimisation and recycling, but improvement recommendations are often focused on recycling. EU/UK legislation is also heavily focussed on driving improved recycling rates, which are easier to apply universally, whilst optimisation opportunities are usually company-specific. Optimisation is more complex, requiring industry know-how including knowledge of the various types of Incremental / Processes & Systems / Structural Change / Core Redesign opportunities presented above, as well as engineering skills, design expertise, commercial perspectives and confidence built on knowledge of similar companies who have made substantial, beneficial improvements.
    c. **Unclear definitions and complex standards**. Many different definitions of 'sustainable' packaging exist, covering a range of topics including biodegradable content, bio-based materials, recycled content, recyclability, and light-weighting. In addition, the common standards that have emerged for sustainable packaging are complex to apply. For example, the Sustainable Packaging Coalition framework comprises 57 metrics, while the Global Packaging Project uses a subset of 22 metrics, only one of which relates to financial topics.

3. **Design**. While many packaging opportunities are stand-alone (e.g. material substitution, packing optimisation), many opportunities require package redesign (e.g. light-weighting, leading to a different package shape; switching from rigid to flexible packaging) or product redesign to allow for different packaging use. In FMCG in particular, where brands are important, redesigning packaging requires the involvement of a broad set of functions from a business, including marketing and brand management. Similarly, packaging sustainability considerations are only now becoming a common part of design processes. Further design

[135] Sources include: Sustainable Packaging Coalition: Sustainable Packaging Indicators & Metrics Framework; The Consumer Goods Forum: A Global Language for Packaging and Sustainability; PwC, 'Sustainable Packaging: Threat or Opportunity?', 2010; PwC, 'Sustainable Packaging: Myth or Reality?', 2012; DEFRA, 'Making the Most of Packaging', June 2009.
[136] For example, DEFRA, Making the most of Packaging – A strategy for a low-carbon economy, June 2009.

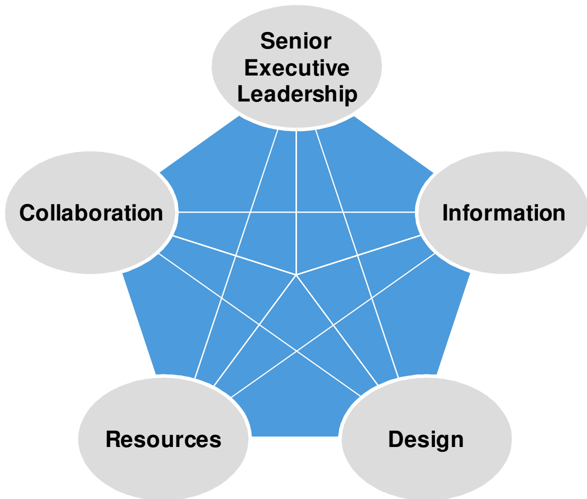
considerations include the emergence of new packaging materials, technologies, manufacturing processes and ever-improving design techniques to extract maximum value from minimal amounts of materials (such as finite element design). This requires the gathering of a range of design capabilities, including from beyond manufacturer's own staff – including packaging producers.

4. **Resources.** Assembling stakeholder requirements of packaging and the relevant internal and external experts (including design capabilities), as well as project managing and facilitating information flows and interactions, requires up-front project investment, which is paid back through better packaging solutions.

5. **Collaboration**. All parties must be willing to contribute their needs and perspectives, as well as actively participate in the design process to ensure that packaging meets their needs. This requires a collaborative attitude which is open to new ideas, including from external parties.

The inter-relatedness of these barriers means that they must all be addressed simultaneously if packaging optimisation is to achieve its full potential.

Figure 41: Packaging Barrier Ecosystem



A range of other issues have been suggested as barriers, but appear to be symptoms of the above-discussed five issues, rather than barriers in their own right. These include:

- Inability to change packaging due to the functional requirements (e.g. impact protection) of the packaging. Optimisation of packaging requirements is an integral part of any change – knowledge of stakeholder requirements (information) and the resources (requiring senior executive leadership) to gather and include this knowledge should alleviate this issue.
- Focus on packaging being 'unimportant' given that it is a small part of the overall waste stream and the improving rate of recycling. Various studies[137] have shown that packaging's environmental footprint is relatively small as a proportion of the packed product's footprint. Senior executive leadership on packaging optimisation should overcome this issue, along with recognition that packaging optimisation is part of the larger profitability and sustainability topic of resource productivity.

[137] See http://www.incpen.org/docs/PackaginginPerspective.pdf and 'Table for One – the energy cost to feed one person', INCPEN, 2009, for examples.

Chapter 6: Circular Resource Flows

This chapter considers products following downstream use (business customers or residential consumers); by-products and rejects created during manufacturing are covered in the Process Waste chapter. Packaging is also covered in a separate chapter.

Chapter Summary

Circular resource use aims to capture the value that exists within products when they come to the end of their linear/first lives (i.e. once their first user has finished with them). It includes product reuse, remanufacturing, cascaded use, recycling and recovery[138].

While recycling rates are high in the UK, there is minimal activity in higher value circular resource flows – e.g. remanufacturing accounts for just **1%** of UK manufacturing sector turnover.
This is despite global pioneers in remanufacturing capturing **95%** of accessible products and using them to generate substantial additional profits. They succeed by retaining control of their products, managing them while in use, resolving reverse logistics challenges, building remanufacturing capabilities and designing for longevity and circular resource use.

Manufacturing sub-sectors that offer the greatest opportunities to capture significant value from circular resource use are:

- Electrical, electronic and optical products
- Machinery and equipment
- Transport equipment

For just these three sub-sectors, remanufacturing can create **£5.6bn to 8bn p.a. of value for manufacturers**, support over **310,000 new jobs** that are skilled and rewarding and reduce UK greenhouse gas emissions.

The key barriers to achieving these remanufacturing benefits are: senior executive leadership, information, skills, design, infrastructure, legal constraints and collaboration.

[138] This chapter examines post-usage products only. Other chapters deal with: Process Waste reduction; Packaging optimisation, and; Transport efficiency.

Introducing Circular Resource Use

Circular resource flow (also called 'Closed Loop') enables society to capture further value from products beyond their initial usage. The types of further value available are:

a. **Reuse** – redeploying a product without the need for refurbishment – e.g. second hand motor vehicles.
b. **Remanufacturing** – returning a product to the Original Equipment Manufacturer (OEM) performance specification and giving a warranty close to that of a newly manufactured equivalent – e.g. Caterpillar has a successful engine remanufacturing business.[139]
c. **Cascaded use** - using a product for a lower value purpose – e.g. turning used clothes into pillow stuffing. This can occur within the operations of a customer, for example where computers are redeployed within a company for less demanding applications.
d. **Recycling** – extracting a product's raw materials and using them for new products – e.g. aluminium and steel are widely recycled.
e. **Recovery** – using a product's materials for a basic, low value purpose such as road base or combustion to produce heat.

In most instances, higher value and greater environmental benefits can be captured from approaches higher up this list. Reuse avoids input costs associated with goods and materials, and also improves labour and equipment utilisation[140]. Recycling, towards the other end of the spectrum, only reduces the cost of materials less the expense of reprocessing. Recovery captures even less value and this often flows to the customer as they dispose of the products; for this reason the value of recovery is not included in this study as a benefit to the manufacturing sector.

It is worth noting that a circular business model is more resilient than a linear production model because when the economy is doing well, resources can be focussed on standard production to meet demand levels which exceed returned product volumes, while in tough economic times, the company can focus on the more cost-competitive remanufactured products and require less input materials to make the same quantity of finished product.

For a manufacturer, pursuing these approaches can lead to improved profitability and competitive advantage, as illustrated in the examples below.

The applicability of circular resource flow to the various manufacturing sub-sectors is presented in Figure 42. Sub-sectors may be more or less suitable for a number of reasons:

- Products that spoil (e.g. food) can only be recovered
- Products that are toxic cannot be recovered or reused without first recycling or remanufacturing them (e.g. certain chemicals)
- Products that degrade or become contaminated (e.g. rubber, plastic, paper, chemicals) cannot be remanufactured without first being recycled
- Products that have a fixed shape cannot easily be cascaded (e.g. machinery)

Note that the rate of technology evolution of a product does not necessarily prevent circular resource flow. Consider the fast-evolving world of mobile phones, for example, which are considered

[139] Remanufacturing is also considered in this study to cover refurbishment.

[140] For some products, where technological development is rapidly improving operating efficiency, reuse may result in higher operating energy use than replacement with a new product (see Gutowski, Y., Sahni, S., Boustani, A. and Grave, S.C. 'Remanufacturing and Energy Savings'. Environmental Science & Technology, 2011, 45, pp. 4540-4547).

technologically redundant within 18 months[141]. While there is little incentive to reuse components in handsets for Western consumers because innovation is a key driver of market success, old handsets are being reused/resold in developing nations[142] and ideas for re-configuration are emerging, such as server farms powered by recovered smart phones.

Figure 42: Applicability of Circular Resource Flow to Manufacturing Sub-Sectors

Sub-Sector	Reuse	Remanu-facturing	Cascaded Use	Recycling	Recovery
Food, beverage and tobacco					✓
Textiles, wearing apparel and leather products	✓	✓	✓	✓	✓
Wood, paper products and printing	✓	✓	✓	✓	✓
Coke and refined petroleum products					
Chemicals and chemical products		✓	✓	✓	
Basic pharmaceutical products and preparations					
Rubber, plastic and other non-metallic mineral products		✓	✓	✓	✓
Basic metals and metal products			✓	✓	
Electrical, electronic and optical products	✓	✓	✓	✓	
Machinery and equipment n. e. c.	✓	✓	✓	✓	
Transport equipment[143]	✓	✓	✓	✓	
Other manufacturing and repair[144]				✓	✓

Only some sub-sectors offer opportunities for higher level circular resource use. Coke, most refined petroleum products[145] and pharmaceutical products do not allow any circularity due to their inherent linearity; they have therefore been omitted from further discussion.

To illustrate circular resource use, consider the following examples. Of note is the development of new business models which often occur to facilitate and capitalise on circular resource flow opportunities; new business models are also discussed in the Revenue Growth chapter of this study.

1. Photocopiers - Fuji Xerox and Ricoh

In the late 1990's, Fuji Xerox, the Australian joint venture between the two companies, was struggling to compete on price selling photocopiers in Australia. Its Japanese-manufactured equipment was more costly than equipment made in lower cost locations. To reduce costs, the company began remanufacturing equipment recovered from its installed base of copiers. This required Fuji Xerox to develop its reverse logistics capabilities/network and set up a remanufacturing site in Australia.

[141] Source: Private correspondence with Anthony Alexander, Research Fellow for Sustainable Supply Chain Management, Cardiff Business School, March 2013.
[142] For example, by Mazuma Mobile. See http://www.ellenmacarthurfoundation.org/case_studies/mazuma-mobile.
[143] Includes manufacture of motor vehicles, parts and accessories for motor vehicles, trailers, ships and boats, railway locomotives and rolling stock, air and spacecraft, military fighting vehicles, motorcycles and bicycles.
[144] Includes furniture, toys, sporting goods, musical instruments, jewellery, and medical and dental instruments and supplies.
[145] A small proportion of petroleum products (those that are not combusted) can be recycled, such as lubricating oils.

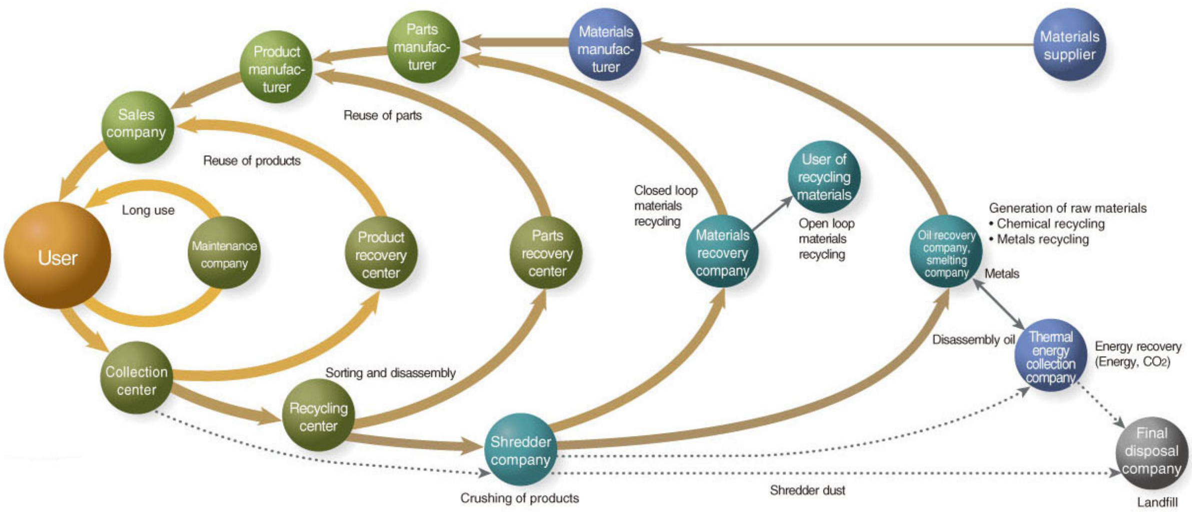
For better control of equipment, and recognising the potential to extend their competitive advantage, Fuji Xerox then altered its business model and relationship with customer to lease copiers instead of selling them (reducing client up-front expense). Because Fuji Xerox owns the copiers, it undertakes maintenance (with the aid of self-diagnostics and predictive maintenance) and designs the equipment for a longer life – greatly improving company profitability and resource efficiency. Note that this remanufacturing model can justify additional materials and up-front investment in the machine to improve longevity, ease of maintenance and ease of remanufacturing.

Using a similar circular approach in the US, Xerox in 2011 recaptured 95% of equipment distributed through direct channels, reused 6% of returned products as complete end items and remanufactured 40% of returned machines including conversion into newer-generation products or parts. Since 1995, Xerox has diverted over 1 million tonnes of product from landfill.

Xerox's new circular business model has created such a substantial competitive advantage and attractive value proposition for customers that other photocopier companies have followed.

Ricoh, for example, has developed a comprehensive circular resource use approach which they call the Comet Circle (see Figure 43).

Figure 43: The Ricoh Comet Circle



Source: Ricoh

2. Gaming Consoles – Sony

Facing increasing competition for customers and wishing to reduce their costs, in the 2000's Sony Computer Entertainment Europe developed a service exchange repair model. This exchanges a customer's faulty product with a remanufactured unit – reducing customer waiting time and removing time pressure from the repair process. The faulty units are then reused (with minor repairs as necessary), remanufactured or used as spare parts – saving on manufacturing of new parts/units. This manufacturing is done in regional centres by outsourced providers – enabling economies of scale.

From 2004 to 2007, 6.8 million parts from both the Playstation and Playstation2 were reused. 85% of consoles required minor repairs, 9% required more complex repair such as replacement of motherboards, and 6% of consoles were irreparable and entered into the component reclamation process[146].

3. Bakery Baskets – Bakers Basco[147]

Recognising the synergies of having a purpose-designed industry standard bakery basket which is reused, in 2006 Allied Bakeries, Hovis, Fine Lady Bakeries, Frank Roberts & Sons and Warburtons formed Bakers Basco to buy, manage and police a new basket: the Omega Basket.

The Omega Basket was designed to reduce bread handling and simplify retailers' replenishment process, enable easier customer identification of products, and be easily returnable. Today around 3 million Omega Baskets are in circulation and Basco's scheme is open to all bakers who can meet the specified criteria (which include care obligations).

Through its operating model, recovery procedures and fines/prosecutions for basket abuse, Basco is reducing basket losses to landfill and abuse – from historical loss rates ranging from 40% to 100%.

4. Ships – Maersk Line

In order to better sort materials upon the breakup of a ship, Maersk Line has developed an online database which will act as an inventory of parts (and their condition) throughout the 30-year life of their ships.

This will enable the tracked materials, including the 60,000 tonnes of steel per ship, to be sorted and processed more effectively towards securing a higher price when sold[148].

National Circular Resource Use Performance

Reuse and cascaded use of products occurs frequently, often on an informal level outside the general market system (e.g. through hand-me-downs, second hand sales, ebay, reuse networks, exchange sites) and are therefore difficult to track. The extent of reuse and cascaded use varies depending on the type of product, mode of failure, residual usage value, and the existence of demand. For some products, including purpose-built products such as spectacles and rapid obsolescence technologies like mobile phones, the reuse markets are in developing nations.

By comparison, remanufacturing rates are low for most manufactured goods. Whilst some value is being generated, for most sub-sectors this represents less than 2% of total sub-sector turnover (see Figure 44). The pumps & compressors and industrial tooling sub-sectors stand out – although even here, the remanufacturing rate is below 10%.

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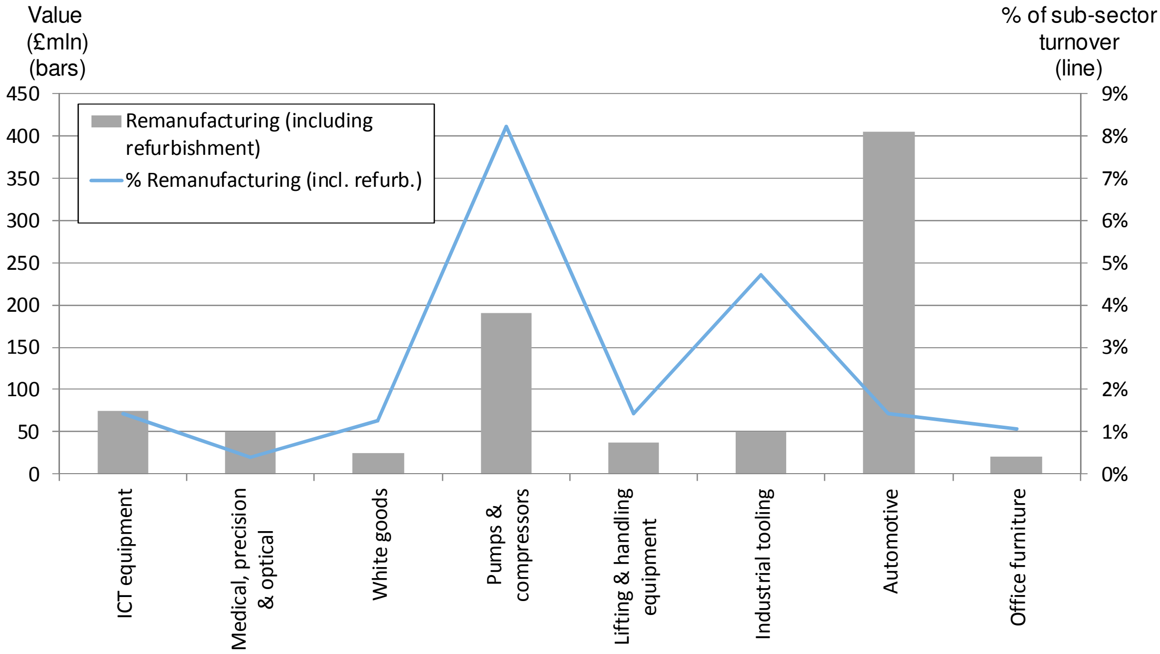
[146] Centre for Remanufacturing & Reuse and EnviroWise, An Introduction to Remanufacturing, 2007, pp. 11-14.
[147] Source: Bakers Basco website http://www.bakersbasco.co.uk/ [accessed 28 May 2013].
[148] Sources: http://www.maersklineroute2.com/articles/how-to-effectively-recycle-168-eiffel-towers; http://www.ellenmacarthurfoundation.org/case_studies/maersk.

Figure 44: Value and Percentage of Sub-Sector Turnover of Remanufacturing(including Refurbishment) for Selected Sectors, 2009



Note: Second hand automobile sales are not counted in the Automotive statistics shown on this graph.
Sources: Centre for Remanufacturing and Reuse, Remanufacturing in the UK: A Snapshot of the UK Remanufacturing Industry, 2009, p. 6; Office for National Statistics, Annual Business Survey, Release Date 17 Nov 2011

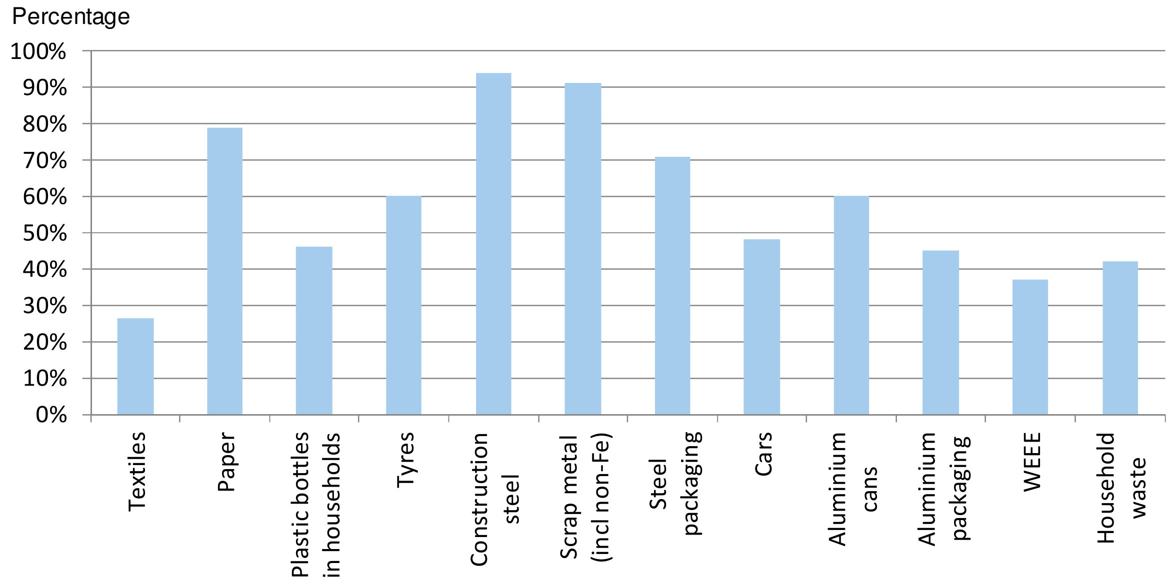
In 2004, the Resource Recovery Forum estimated the value of remanufacturing in the UK at £5 billion[149]. This figure was similar in 2009 when the study was refreshed[150]. Compared with the total turnover by the UK manufacturing sector in 2011 of £512 billion[151], remanufacturing represents approximately 1% - consistent with Figure 44.

Recycling performance in the UK varies significantly depending on the material, its value, the ease of recycling and regulation.

Figure 45 demonstrates this variance across a range of products. Recycling rates shown are from 26% to 94% - all significantly higher than remanufacturing. A number of the lower recycling rates occur where materials are embedded within products amongst other materials – suggesting the need for better product design to enable easier separation (e.g. cars, waste electrical and electronic equipment).

[149] Source: Resource Recovery Forum, Remanufacturing in the UK: a significant contributor to sustainable development?, 2004.
[150] Source: Centre for Remanufacturing and Reuse, Remanufacturing in the UK: A snapshot of the UK remanufacturing industry, 2009, p. 6.
[151] This value is for the whole of SIC Section C Manufacturing. Source: Office for National Statistics, Annual Business Survey, Release Date 15 Nov 2012.

Figure 45: UK Recycling Rates for a Selection of Products

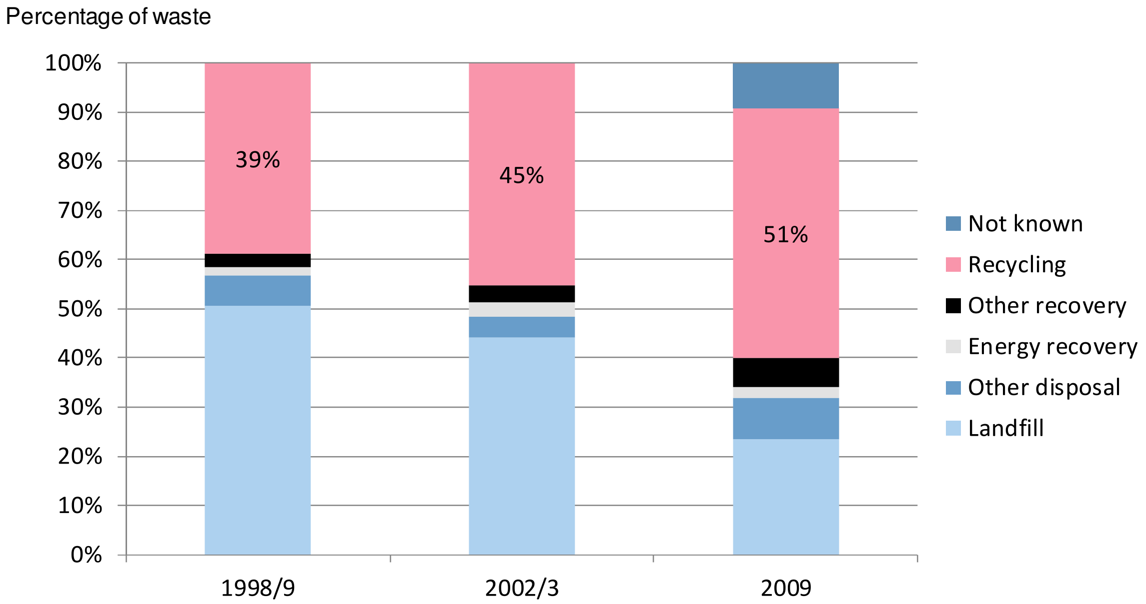


Note 1: Figures are for latest year that data was available (see sources below). This was mostly 2008 to 2010.
Note 2: WEEE refers to Waste Electronic and Electrical Equipment
Sources: http://www.letsrecycle.com/prices/textiles; http://www.just-style.com/management-briefing/closing-the-loop-on-recycled-textiles_id113954.aspx; Confederation of Paper Industries, 22 March 2011 press release; http://www.cleaning-matters.co.uk/stories/articles/-/newsletters/2012/march2012/uk_paper_recycling_rate_reaches_78_7_in_2011/;http://www.bpf.co.uk/sustainability/plastics_recycling.aspx; http://recyclerubber.wordpress.com/; http://www.letsrecycle.com/news/latest-news/waste-management/uk-leads-europe-on-tyre-recycling; http://www.unep.org/resourcepanel/Portals/24102/PDFs/Metals_Recycling_Rates_110412-1.pdf; http://www.steelconstruction.info/Recycling_and_reuse; http://www.recyclemetals.org/about_metal_recycling; http://www.mpma.org.uk/pages/pv.asp?p=mpma68; https://www.itri.co.uk/index.php?option=com_zoo&task=item&item_id=2390&Itemid=155; https://www.keynote.co.uk/market-intelligence/view/product/10325/metal-recycling; http://www.environment-agency.gov.uk/cy/ymchwil/llyfrgell/data/34425.aspx; http://www.letsrecycle.com/news/latest-news/metals/uk-aluminium-can-recycling-rate-jumps-to-55; http://www.aluminiumtoday.com/news/view/uk-achieves-60-recycling-rate-for-drinks-cans; http://www.letsrecycle.com/news/latest-news/weee/uk-weee-recycling-rate-below-european-average; Hampshire CC WEEE Agenda Item 6, p. 2. Numbers consistent with WRAP figures; WRAP, Plastics Market Situation Report, 2010; http://www.wastecare.co.uk/england%E2%80%99s-recycling-rate-at-42/

Rates of recycling in the UK have been rapidly improving in the last decade (see Figure 46 for Commercial and Industrial sector recycling in England and also the Packaging chapter of this study), driven by a combination of rising commodity costs, increasing landfill costs and increased national and European Union legislation and target-setting[152].

[152] For details of the landfill tax, accompanying legislation and their impacts on waste management practices (including recycling) in the manufacturing sector, please refer to the Process Waste chapter of this study.

Figure 46: Waste management for England's Commercial and Industrial Sectors



Note: Reuse (which was 2% for 2009) has been included in recycling for this graph only to enable comparison with 1998/9 and 2002/3 numbers, which do not break out reuse.
Sources: e-Digest of Environmental Statistics, Published September 2005, Defra, http://www.defra.gov.uk/environment/statistics/index.htm ; Commercial and industrial waste generation and management, Defra, 2010, http://www.defra.gov.uk/statistics/environment/waste/wrfg03-indcom/

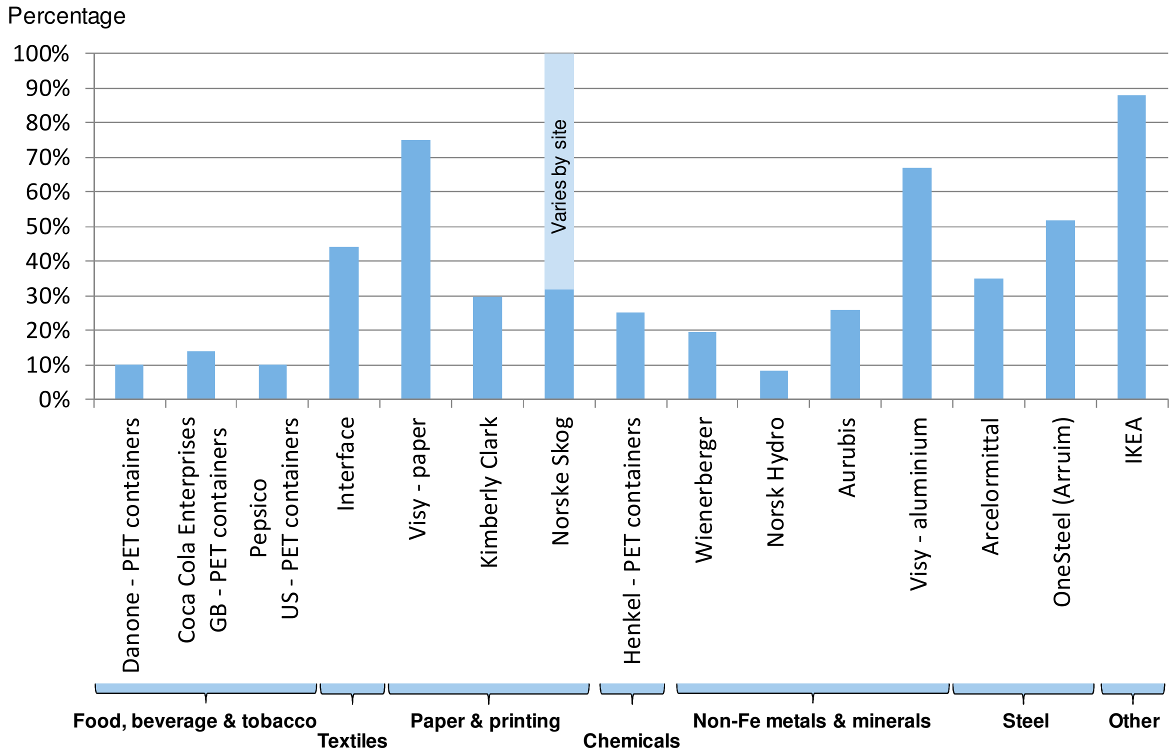
In summary, while significant reuse and cascaded use is likely occurring in the UK and recycling is varied but improving, remanufacturing is limited – presenting an opportunity for UK manufacturers.

Best Practice in Circular Resource Flow

Use of recycled/renewable[153] material by manufacturers varies substantially between sectors and companies within sectors (see Figure 47)[154]. For paper, recycled content varies from 30% to 100%, aluminium from 8% to 67%, and steel from 35% to 52%.

[153] Figures for consumed recycled material are often combined for corporate reporting purposes with renewable material used. The term renewable refers to material that comes from a naturally replenishing source, such as timber.
[154] Note that recycling of internal waste is not included in this analysis. Global best practices for production waste, as well as the potential improvement opportunities that they represent for UK manufacturing, are presented in the Process Waste chapter of this study.

Figure 47: Percentage of Recycled or Renewable Content Used in Products in 2010 or 2011



Sources: Company Annual Reports, Sustainability Reports, websites; Next Manufacturing Revolution survey

This variation within sectors suggests a substantial opportunity for some manufacturers to increase the use of recycled material in their products and packaging, since leaders in several manufacturing sub-sectors are achieving over 60%. For some sub-sectors, increased use of recycled inputs will be facilitated by rising rates of recyclate capture.

A number of leading companies have moved beyond recycling to access greater value. Xerox, for example, recaptures 95% of equipment sold through direct channels[155]. Caterpillar successfully captures 95% of eligible end-of-life returns[156].

> "Cat Reman offers more than 6,000 part numbers ranging from 1-pound fuel nozzles to complete 16,500-pound engines. It remanufactures more than 2.3 million components annually and ships 9,000 units on an average day. Over the past five years, Cat Reman has grown from 800 employees and three facilities to more than 3,600 employees and 18 facilities. It has expanded geographically from two countries to seven countries, and nearly tripled its revenue"[157].

The value achieved by leading companies through reuse and remanufacturing is substantial:

- Cisco (electrical, electronic and optical sub-sector) reused 45% of returned equipment in 2008, creating additional profit of $100million[158]
- In 2009, Caterpillar remanufactured over £130million worth of material[159]

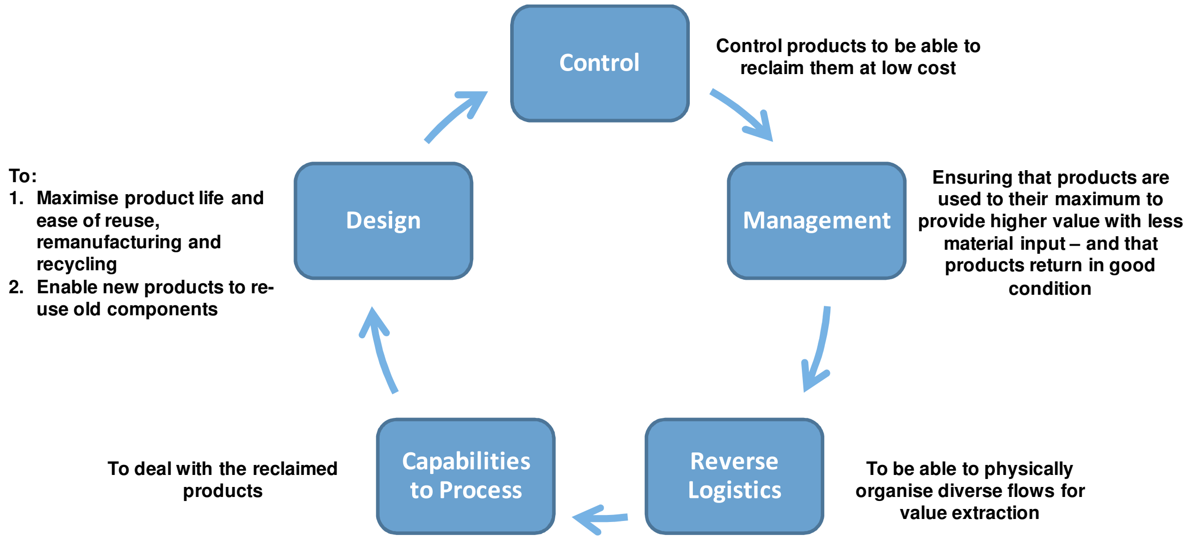
[155] USA figure. Source: Xerox Environment, Health and Safety Report, 2011, p. 14.
[156] Source: Caterpillar Sustainability Report, 2011, p. 68.
[157] Hegland, D. Remanufacturing Is Profitable and Green, Assembly Magazine, 24 Feb 2010, http://www.assemblymag.com/articles/84787-remanufacturing-is-profitable-and-green.
[158] Source: RCM, Sustainability: Opportunity or Opportunity Cost, 2011, pp. 6, 9.
[159] EEF, Ascending the Waste Hierarchy, Sep 2011, p. 10.

- Renault's remanufacturing business generates €200million in revenue per annum[160]

How Good Practice Companies Improve their Circular Resource Flow

Best practice companies have moved as far to the left in Figure 42 as possible – maximising use of products at the end of their first lives. To do this they have addressed five different aspects of their businesses in parallel, creating a virtuous cycle that has enabled them to significantly reduce their costs (see Figure 48). Achieving this has required alteration of their processes and systems, structural changes and, in many instances, core redesign of their business models[161]. Note that companies need not do every step in the virtuous cycle in-house; partnerships with other companies with appropriate competencies are common.

Figure 48: Virtuous Cycle for Capturing the Value of Circular Resource Flows



Explaining the five steps in more detail:

1. **Control of Products**

   Control of a product beyond its life with the first customer is important to enable the manufacturer to secure the return of valuable resources/parts/equipment at low cost[162]. To do this a range of business models have been developed, including offering services instead of products (e.g. power instead of aircraft engines), leasing (e.g. of photocopiers), incentivised return and reuse (e.g. deposit schemes, discounts on replacements), ownership of waste streams (e.g. refuse contracts) and collection schemes (e.g. for specific products such as paper/cardboard).

[160] Source: Ellen Macarthur Foundation, Towards the Circular Economy, EMF, 2012, p. 28.
[161] Business models are discussed in detail in the Revenue Growth chapter of this study.
[162] Losing control of a product results in it being sold back to the manufacturer at just below the cost of the alternative (i.e. virgin raw materials). This means that other parties secure disproportionate value from closing the loop; value which in many cases could significantly improve the profitability of the manufacturer.

2. Product Management

Through managing their products while they are being used, manufacturers can maximise product use and improve the condition of their products when they are returned, enabling greater reuse and minimising refurbishment costs. The cost of maintaining products can be minimised by manufacturers, for example, through their correct scheduling of maintenance, the inclusion of self-diagnostic software and early-warning telemetry and/or the use of statistical analysis of all products to predict maintenance needs.

3. Reverse Logistics

One-way linear resource and product supply chains do not often support circular resource flow. For example, siting a production facility next to a major input resource and then transporting products a long distance to customers makes return transport of products to the plant expensive. Leading companies have therefore optimised their footprints and logistics to enable their products to cycle easily and inexpensively to and from customers multiple times.

4. Capabilities to Process

Companies adopting circular resource use must have the facilities and capabilities to receive back products at the end of their first life and reprocess them – whether these capabilities are in-house or outsourced. Ricoh, for example, in their Comet Circle[163], have a network of capabilities and facilities around maintenance, collection, product recovery, recycling, parts recovery, and materials recovery which feeds into their suppliers and their own supply chains.

5. Design for Circular Resource Flows

Good product design can substantially reduce the cost of product circularity. Aspects include developing 'timeless' designs, choosing recyclable materials, reducing the number of materials, ensuring interchange-ability of parts between models, designing new products to re-use old components, designing for disassembly, optimising product designs for multiple life-spans, ensuring products can easily be cleaned, incorporating self-diagnosis, improving maintenance access and designing in flexibility for future upgrades and retrofits. Most companies currently design for fashion and obsolescence which suits a linear product model where maximising one-time revenues is the aim.

The Full Potential of Remanufacturing for UK Manufacturing

Given the focus of this study on the value potential of the Next Manufacturing Revolution to UK manufacturers (as well as social and environmental benefits to the community), the financial upside of increased rates of post-consumer recycling is not considered[164]. For most products in today's linear consumption pattern, the manufacturer passes control of the products to the customer; any recycling value is therefore obtained by the customer/waste processor and not by the manufacturer[165]. Increased recycling also has environmental and social benefits in the form of reduced landfilling and increased employment in the recycling value chain; these have similarly not been quantified because the value accrues to parties outside of the manufacturing sector.

[163] See Ricoh's 2011 Sustainability Report, p. 15.
[164] Note that recycling of manufacturers' operational waste is considered in the Process Waste chapter.
[165] The price of recycled materials often sits marginally below that of virgin materials, so there is no significant financial benefit for the manufacturer – this benefit is kept by the customer and the recycling value chain.

Remanufacturing, however, offers substantial benefits to sectors where it can be used. It is particularly attractive for products which are:

- Higher value
- Durable
- De-personalised (i.e. not lifestyle, fashion or status oriented)
- Stable in their underlying technology over more than one life cycle
- Delivered as services instead of hardware – i.e. where goods can be substituted by services (e.g. providing light instead of light bulbs). Where this occurs, there are shared motives for product longevity, durability and performance[166].

The sub-sectors recognised as having the greatest potential value through remanufacturing are therefore:

- Electrical, electronic and optical products (including computers and other ICT equipment, medical devices, appliances, and electrical motors)
- Machinery and equipment (including engines, pumps, compressors, lifting equipment, office equipment excluding ICT, agricultural machinery, and industrial tools)
- Transport equipment (including aircraft, rail rolling stock, commercial vehicles, fleet motor vehicles, and private cars[167]).

Remanufacturing costs are driven by the five steps involved in remanufacturing:

1. Collection – involving a reverse transport leg, expected to be as long as the outward journey.
2. Disassembly, cleaning and inspection – requiring labour assumed to be equivalent to that required for assembly, as is the case for Xerox[168].
3. Reconditioning/replacement – assumed to amount to a fraction of the effort required for pre-assembly activities that occur with new-build products.
4. Reassembly – assumed to be the same as the original product assembly.
5. Transport to market – likely to be as far as the original journey from plant to market.

The major benefit of remanufacturing is substantially reduced input costs – specifically materials, base materials preparation (e.g. casting, forming), machining, and energy. Data on the magnitude of this saving (summarised in Figure 49) includes:

- Ricoh, who note that their remanufactured photocopiers have a manufacturing greenhouse gas emissions footprint 90% lower than the equivalent new copier[169]
- Giuntini & Gaudette[170] who cite 85% energy use reduction through remanufacturing
- The EEF has noted that remanufactured products such as diesel engines can have 85 per cent lower energy costs and 60 per cent lower material costs than new counterparts[171].
- The Advanced Remanufacturing and Technology Centre in Singapore notes that, compared with new components, remanufactured components save >60% energy, >70% materials, >90% water, and >80% pollutant emissions, while retaining >80% of the product's value[172].

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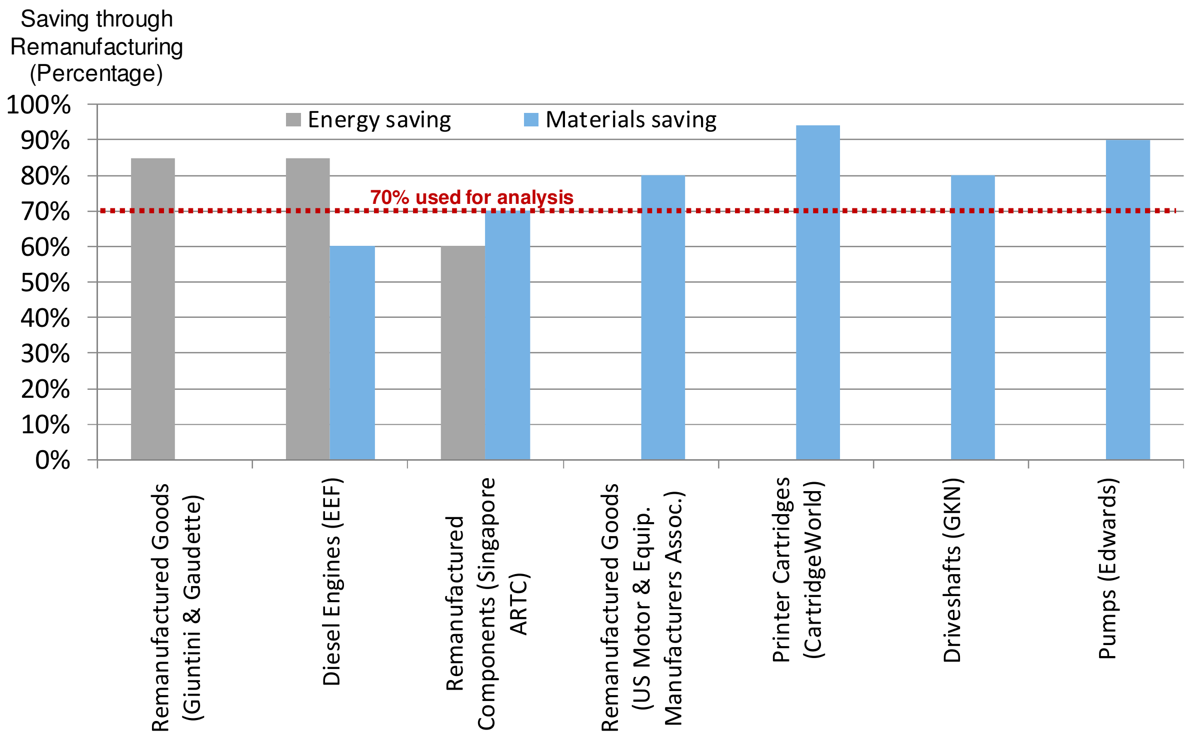
[166] Note that B2B situations increase the manufacturer's ability to manage the usage and end-of-life actions.
[167] It is recognised that private vehicles which are currently to a large extent fashion–driven purchases and that remanufacturing may take some time to be accepted by private car buyers. Private cars are therefore specifically addressed in the remanufacturing opportunity value calculations below.
[168] Xerox use double the labour for remanufacturing compared to linear manufacturing. Source: Gray, C. Charter, M. Remanufacturing and Product Design: Designing for the 7th Generation, The Centre for Sustainable Design, University College for the Creative Arts, Farnham, 2007, p. 36.
[169] Ricoh Sustainability Report, 2011, p.31.
[170] Giuntini, R., Gaudette, K. Remanufacturing: The next great opportunity for boosting US productivity, Business Horizons, Nov-Dec 2003, p. 44.
[171] EEF, Ascending the Waste Hierarchy, Sep 2011, p. 10.

- The US Motor & Equipment Manufacturers Association testified to the International Trade Commission on Remanufactured Goods that: "Remanufacturing saves 80% of the energy and material used to manufacture equivalent new parts"[173].
- CartridgeWorld saves 94% of materials when it remanufactures printer cartridges[174].
- GKN reuses 80% of the steel in recovered driveshafts through remanufacturing[175].
- Edwards remanufactures over 90% by weight of a pump's components – with a corresponding saving in raw materials and their embodied carbon dioxide[176].

Figure 49: Savings through Remanufacturing



Based on this data, for this analysis it is assumed that 70% of goods, materials and services is saved through remanufacturing[177].

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[172] Advanced Remanufacturing and Technology Centre website http://www.artc.a-star.edu.sg/about-artc/remanufacturing.aspx.
[173] McKenna, R. President and CEO, Motor & Equipment Manufacturers Association, Testimony before the International Trade Commission on: Remanufactured Goods: An Overview of the U.S. and Global Industries, Markets, and Trade, Investigation No. 332-525, Feb 2012.
[174] Centre for Remanufacturing and Reuse, The carbon footprint of remanufactured versus new mono-toner printer cartridges, http://www.remanufacturing.org.uk/pdf/the_carbon_footprint_of_remanufacturing_printer_cartridges.pdf
[175] GKN Land Systems website http://www.gkn.com/landsystems/brands/gkn-pss/remanufacturing/Pages/default.aspx.
[176] Edwards website http://www.edwardsvacuum.com/Corporate/CorporateResponsibility/Environment.aspx?cID=5835.
[177] Note that to extend a product's useful life through multiple remanufacturing cycles, additional resources may be invested in its initial manufacture. Such an investment may also result in lower remanufacturing costs. This is not included in this analysis but should be a part of the lifecycle economic and footprint analyses for new products.

In summary, the cost for remanufacturing involves, at a high level, twice the labour required for new products, and twice the transport, but saves 70% of input goods, materials and services. Given that the average spend across the whole UK manufacturing sector in 2010 for goods, materials and services was 66% of revenue, labour 18% and transport a small proportion, the net reduction in input costs (goods, materials & services plus labour) through remanufacturing is 34%.

This is lower (and therefore more conservative) than the typical range of input cost savings of 40% to 65% identified by Giuntini & Gaudette[178] for the US.

In terms of revenue, it is recognised that it is appropriate to apply a price discount to ensure that market shares are maintained with remanufactured goods. The effective price charged for a remanufactured product varies depending on the nature of the product and its remanufactured condition, who it is sold to (business versus consumer) and whether it is part of a leased service. Remanufactured products, when sold against new products, are typically priced to consumers at around 30 to 40% less than similar new products[179]. On the other hand, according to the Centre for Remanufacturing and Reuse, refurbished PCs and laptops are generally sold at prices 10 to 15% lower than for the equivalent 'new' product[180]. Remanufactured products in service applications are effectively priced the same regardless of how old they are; Xerox and Ricoh charge customers per copy regardless of whether a machine is remanufactured or brand new (and they all look brand new).

For this analysis, a 20% price discount has been used – the mid-point of the range of price discounts cited. This implies that a significant proportion of remanufactured products will be sold as a service; extrapolating current trends in this direction (including the development of new business models – see the Revenue Growth chapter) suggests that this is a reasonable.

The resulting net impact (using average UK manufacturing figures) is that profitability (EBITDA) is improved from the current 16%[181] to a higher figure for where remanufacturing occurs of 30%[182]. This is consistent with the views of:

- Giuntini, advisor at The Remanufacturing Institute, who notes: "Profit margins on the sale of remanufactured goods can be as high as 40%."[183]
- Steinhilper, author of *Remanufacturing: The Ultimate Form of Recycling*, who commented that remanufacturing can be twice as profitable as primary manufacture[184].

Current rates of remanufacturing are low. Figure 44 and the Resource Recovery Forum[185] estimate current rates of remanufacturing of around 1%.

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178 Giuntini, R. Gaudette, K. Remanufacturing: The next great opportunity for boosting US productivity, Business Horizons, Nov-Dec 2003, p. 44.

179 Giuntini, R. Gaudette, K. Remanufacturing: The next great opportunity for boosting US productivity, Business Horizons, Nov-Dec 2003, p. 43.

180 Centre for Remanufacturing and Reuse, Remanufacturing in the UK: A snapshot of the UK remanufacturing industry, 2009, p. 23.

181 From: (100% revenue - 66% goods & services – 18% labour)/100% revenue = 16% EBITDA margin

182 Calculated as: (80% revenue with price discount – 66% goods & services x 30% due to reman saving – 18% labour x 200% for reman)/80% revenue = 30% EBITDA margin

183 Source: Hegland, D. Remanufacturing Is Profitable and Green, Assembly Magazine, 24 Feb 2010, http://www.assemblymag.com/articles/84787-remanufacturing-is-profitable-and-green.

184 Steinhilper, R. Interview by Gray, C, 22 Nov 2006, in Gray, C. Charter, M. Remanufacturing and Product Design: Designing for the 7th Generation, The Centre for Sustainable Design, University College for the Creative Arts, Farnham, 2007, p. 2.

185 Source: Resource Recovery Forum, Remanufacturing in the UK: a significant contributor to sustainable development?, 2004.

In order to determine a reasonable full potential percentage of products that can be remanufactured, Xerox provides a good practice case study. As discussed above, Xerox is reusing 6% of returned equipment and remanufacturing a further 40% - a total of 46%. It is therefore assumed for this study that a 50% remanufacturing rate is a reasonable target, recognising that this will take some time to achieve.

Applying the above set of assumptions to the three key sub-sectors of interest identified earlier suggests full potential benefit for UK manufacturing of **£5.6 to 8 billion per annum in EBITDA**[186,187] and an **additional 310,000 to 320,000 jobs**[188,189,190], based on 2010 figures[191].

Figure 50 shows the impact of full remanufacturing on the three sub-sectors examined: Electrical, electronic & optical products, Machinery & equipment, and Transport equipment[192].

[186] EBITDA = Earnings before interest, tax, depreciation and amortisation and is a profit metric measured by companies. It does not account for the additional capital expense required to establish remanufacturing, which would comprise the space and equipment to disassemble products and cleaning and refurbishment equipment.

[187] Calculated for upper end of estimate as 50% of (2010 revenue for 3 in-scope sub-sectors of $140bln x 80% for price reduction – 30% x £98bln of goods, materials and services – 200% x £24bln of labour cost) - £9.3bln which is current EBITDA = £8bln p.a. based on 2010 figures. It is recognised that energy savings from remanufacturing were included in the Energy Efficiency chapter; this is considered to be a negligible overlap given that energy costs typically represent less than 3% of goods, materials and services purchased by manufacturers.

[188] Calculated for upper end of estimate as 50% of products remanufactured x 2010 labour force for the 3 in-scope sub-sectors of 650,000 adjusted down for current 1% remanufacturing = 320,000 additional jobs.

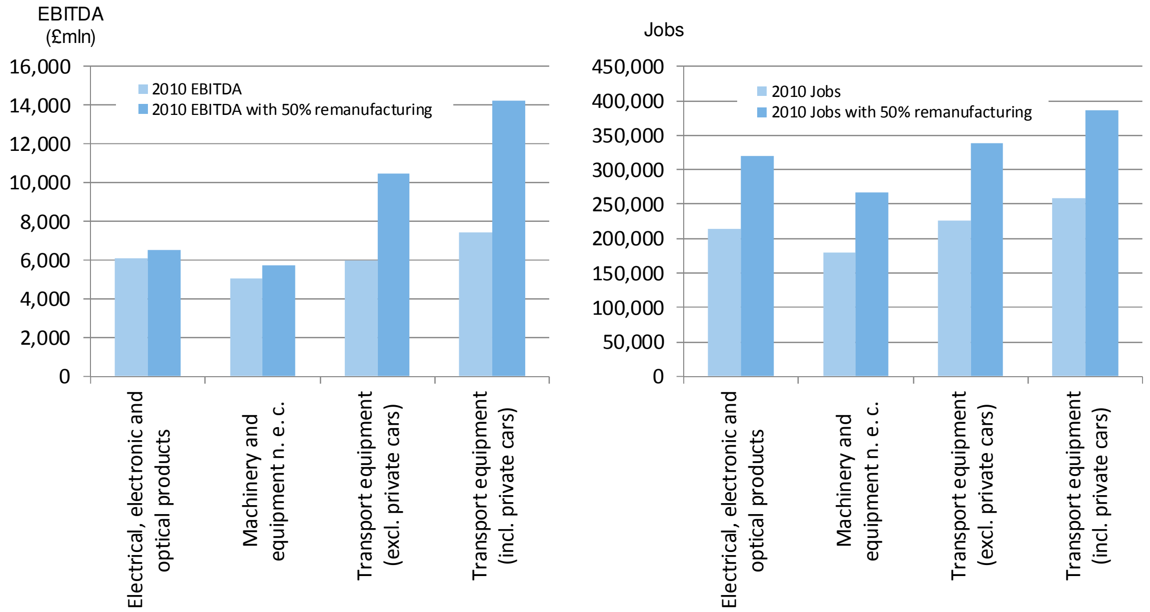
[189] Note that remanufacturing jobs are more varied and skilled than conventional assembly line work due to the need for careful diagnosis and judgement in deciding which parts can be remanufactured and variety of condition of recovered equipment requiring staff to adapt their activities to suit each piece of equipment's individual remanufacturing needs.

[190] This number of jobs is consistent with an additional spend on labour of £24bln – i.e. £76,000 per position.

[191] The opportunity for circular flow of process wastes (e.g. scrap, rejects, start-of-run production) in industry is covered in the Process Waste chapter.

[192] Two figures are shown for the Transport equipment sub-sector: without and with private vehicles being remanufactured, recognising that fashion/status purchasing may continue to motivate private car buyer behaviour for a long time.

Figure 50: Impact of Full Remanufacturing on EBITDA and Jobs in the Three In-Scope Sub-sectors



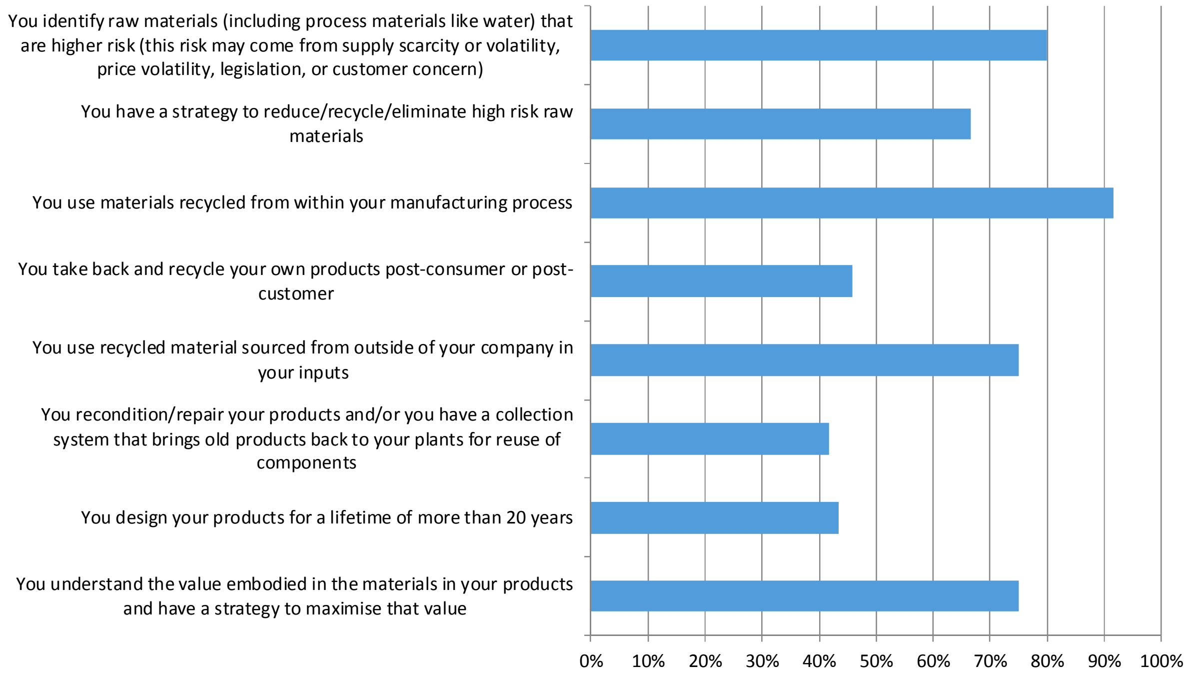
Sources: Society of Motor Manufacturers and Traders, Motor Industry Facts 2012, ; Office for National Statistics, Annual Business Survey, Release Date 17 Nov 2011

Comparing these results with other research, the Ellen MacArthur Foundation circular economy report[193] estimated the potential of remanufacturing in similar sectors to those examined in this work, for the European Union as a whole. Pro-rating their results to the UK based on GDP, their 'transition' case for remanufacturing represents a £30 to 34billion per annum saving in materials. Their 'advanced' case estimated potential materials cost savings of £47 to 57billion per annum. These 'transition' case figures align with the £30 to £34billion saving in goods, materials and services calculated in this study.

The Next Manufacturing Revolution survey[194] results (see Figure 51) suggest strong recycling behaviour, but substantial opportunities in reuse and remanufacturing, consistent with the broader findings of this study. However, the stated behaviour of respondents regarding reconditioning/repairing is much higher than the above research would suggest, consistent with a sample bias given the good sustainability track records of survey participants.

[193] Ellen Macarthur Foundation, Towards the Circular Economy, 2012, p. 66.
[194] See Appendix 3 for details of the survey.

Figure 51: Results of Next Manufacturing Revolution Survey Questions Regarding Materials & Recycling: Percentage of Respondents Agreeing with the Statements[195]



Circular resource flows have a number of non-monetary benefits. Reduced use of virgin resources means greater availability for future generations and less environmental damage and pollution from their extraction, processing and transport. These environmental benefits mostly occur overseas.

In the UK, greater recycling, reuse and remanufacturing means that fewer landfill sites and incineration facilities are needed. Having fewer manufacturing steps also generates environmental benefits from reduced greenhouse gas emissions as well as other pollutants generated in the processing of raw materials into parts. Note that the greenhouse gas emission reductions from remanufacturing are included in the Energy Efficiency chapter so are not repeated here to avoid double counting.

[195] Note that the survey only gave the response options of 'yes' and 'no'.

Barriers to the Adoption of Circular Resource Use

There are four main barriers to achieving the full potential of remanufacturing[196] as illustrated in Figure 52, which are interdependent:

1. **Senior executive leadership**. Changing the perceptions of an entire organisation and its customers is a difficult task requiring the skills, experience and influence of senior executives. Significant resources may be required to establish new capabilities and/or infrastructure (e.g. reverse logistics). Only senior executives can drive a change of culture and/or business model, should this be necessary (e.g. to a service or leasing model).

   > "Jack Welch articulated a vision for GE that included adding value to GE capital goods already in use through a combination of remanufacturing and upgrades. He committed resources, including engineering and R&D, to achieving this high level of customer value. As a result, around 35% of GE Capital's 2001 revenues came from other-than-new product and service activities, accounting for more than 60% of profits. This performance was the direct result of Welch's top-level commitment to remanufacturing"[197].

   Changing a business model challenges existing business practices. For example, amongst all of the departments in a company who must retune their approach for remanufacturing, one of the most important is the sales team – the face of the company and the key to the success of a product. Salespeople prefer to sell what they know using tried and proven techniques to hit their short term sales targets. New offerings and new customer segments present risks to salespeople and therefore require sales training and incentives to shift attention to remanufactured products and address an often hard-wired belief that remanufactured products are a threat to their new sales commissions. Senior executive leadership is vital to achieving this shift.

2. **Information.** Two major information issues exist:

   a. ***Awareness*** of potential untapped profits. Remanufacturing is not broadly understood; to an organisation focussed on linear production, it can often be dismissed as risky due to concerns about brand damage or sales cannibalisation. Companies are rarely aware of the superior profit margins available and their ability to reach new customer segments without harming (in fact sometimes enhancing) their brands through remanufacturing.

[196] Sources include: Resource Recovery Forum, Remanufacturing in the UK: A significant contributor to sustainable development? 2004; Giuntini, R. Gaudette, K. Remanufacturing: The next great opportunity for boosting US productivity, Business Horizons, Nov-Dec 2003; Gray, C. Charter, M. Remanufacturing and Product Design: Designing for the 7th Generation, The Centre for Sustainable Design, University College for the Creative Arts, Farnham, 2007; Centre for Remanufacturing and Reuse, Remanufacturing in the UK: A snapshot of the UK remanufacturing industry, 2009; Willis, P. Market Failures in Remanufacturing, Centre for Remanufacturing and Reuse, Mar 2010; Ellen Macarthur Foundation, Towards the Circular Economy, 2012; Parliamentary Office of Science and Technology, Maximising the Value of Recycled Materials, Houses of Parliament, POSTNOTE 425, Jan 2013; Next Manufacturing Revolution survey.

[197] Welch, Jack. 1999. Letter to share owners, employees, and customers. General Electric Corp. www.oemservices.org/opi_products.html. in Giuntini, R. Gaudette, K. Remanufacturing: The next great opportunity for boosting US productivity, Business Horizons, Nov-Dec 2003.

b. ***Inconsistent use of the term 'remanufacturing'*** was noted in the literature as a barrier, leading to confusion and misunderstanding over remanufactured products. Clarification of terminology and proper recognition – for example by published standards – is recommended to address this issue[198]. This is considered to be a part of the information challenge.

3. **Skills**. Very few people have developed circular resource use companies from start-up; even fewer have transformed a large company from a pre-existing linear model because very few companies have undergone this transition. The skills required include strategic thinking, engineering, marketing, logistics, process design, and change management.

4. **Design**. Product design plays a crucial role in the success of manufacturing because it directly impacts on the ability of a company to monitor, disassemble, inspect, and reassemble remanufactured products. All of these impact labour cost and hence heavily affect the economics of remanufacturing (and recycling). Difficult disassembly, irreversible closures, tight access, specialised tool requirements, multiple materials (especially plastics), surface coatings, glues and labels, and insufficient materials information all need to be avoided through good design.

> "GE Medical Systems wanted to test the profitability of a voluntary take-back and remanufacture of their used equipment. To test it, a manager was asked to run a pilot in an old plant for a year, after which period he had to report if it was profitable. The reply was: 'Yes, we can break even, but if the products were designed for remanufacture, then we could have made a lot of money.'"
>
> - Walter Stahel, The Product-Life Institute[199]

Modular design allows technological upgrades to be incorporated easily during the remanufacturing process, reducing obsolescence and maintaining the competitive positioning of the resulting products compared to new ones.

Good design enables rapid, easy disassembly and sorting. It eliminates consumables (just as the Dyson company have eliminated bags from vacuum cleaners) and maximises resource efficiency during the product's use phase.

Design is important also to maximise the longevity of a product both physically and stylistically. Examples of enduring designs which also facilitated/encouraged remanufacturing include aircraft, spacecraft, Vitsoe shelving units, the VW beetle, E-type Jaguar, and Rolex watches – as well as more recently Xerox and Ricoh photocopiers.

Several peer reviewers noted that design is the most important factor for enabling remanufacturing.

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[198] In 2011, the British Standards Institution published a quality mark (PAS 141) for re-used electrical goods to reassure customers that re-used electrical and electronic equipment is safe (source: Hopperton, L. 'E-waste: How industry associations are helping engineers design for reuse and recycling', New Electronics (online) 08/05/2012, http://www.newelectronics.co.uk/electronics-technology/industry-associations-help-engineers-think-about-design-for-reuse-and-recycling/42131/ [Accessed on 21/08/2012]).

[199] Speaking at the Remanufacturing Stakeholder event, 2007 in Gray, C. Charter, M. Remanufacturing and Product Design: Designing for the 7th Generation, The Centre for Sustainable Design, University College for the Creative Arts, Farnham, 2007, p. 23.

5. **Recovery infrastructure**. This refers to both hardware and systems and has two aspects, both raised in the Process Waste chapter:

    a. ***Scale***. The diffuse and irregular supply of post-consumer products is complicated by variation in recycling systems across England and the volumes of recyclate being exported. This makes it difficult to assemble a large steady stream of high quality feedstock for scale processing – increasing the cost of recovery infrastructure due to sub-scale operation.

    b. ***Supply and demand dilemma.*** Remanufacturers are unable to commit to large offtake agreements without surety of supply and it is difficult to create consistent supply without offtake agreements. Investing in recovery infrastructure is therefore risky for private investors.

    This barrier has begun to be addressed, with WRAP and the UK Green Investment Bank provide funding to help start up new recycling processes, voluntary agreements linking participants and providing security for investors, and corporate social responsibility commitments driving volumes.

6. **Legal constraints**. These primarily consist of legal impediments and access to product information.

    a. ***Regulatory impediments***. The regulatory impediments to remanufacturing are wide-ranging. They include:
        - Banning of remanufactured components in new goods
        - The UK Sales of Goods Act (SoGA) which discourages retailers from retailing used goods
        - Definitions of waste that hinder trade and transport of products for remanufacturing
        - Classification of remanufactured products as 'used', which gives the impression of a second-rate or unsafe product
        - Legislative focus on recycling which can preclude or at least make remanufacturing difficult e.g. incentivising of recycling of scrap rather than re-use or refurbishment for Waste Electrical and Electronic Equipment
        - EU Regulation, Evaluation, Authorisation and Restriction of Chemical (REACH) rules, specifically Article 33 (1) which requires contract manufacturers and distributors who supply an article which contains more than 0.1% weight by weight of any Candidate List Substance of Very High Concern to provide their industrial customers with sufficient information to allow safe use of the article including, as a minimum, the name of that substance. Compliance can be difficult for remanufacturers, especially if they did not produce the product in the first place.
        - Safety and environmental regulation that can limit the reuse of vehicle parts, even with design changes for modularisation.

b. ***Product information***. Denial of access to manufacturer design information including manufacturing specifications and tolerances, anti-remanufacturing devices being introduced by Original Equipment Manufacturers (OEMs) to thwart independents, and efforts to prevent reverse engineering are discouraging third party remanufacturers.

Solutions are beginning to emerge that respect intellectual property rights, such as product databases/passports as used by Maersk Line. Peer-to-peer repair sites are also emerging, such as iFixit, who develop free repair manuals for smart-phones and games consoles as well as the necessary parts and tools.

In contrast, the USA operates under the Freedom of Information Act, which allows general access to product information.

7. **Collaboration** – especially customer acceptance of circular products. Two aspects of customer perception are especially important:

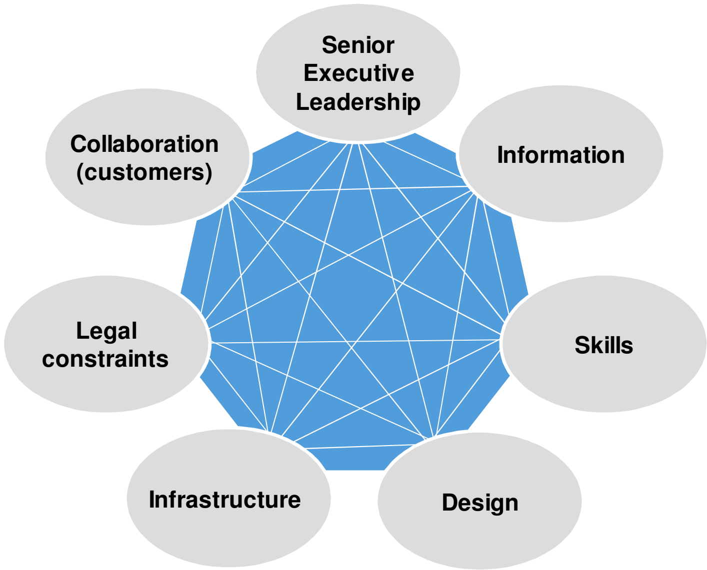
    a. **Changing the throw-away culture**[200]. In a 'linear' world, production profits are maximised by increasing the number of items sold. Therefore, managed obsolescence through equipment failure, changing fashion trends, minor technical upgrades, and other cosmetic and image-related changes have become the norm for many manufactured goods. Turnover of goods has been encouraged further by low cost products made in Asia. Increasing affluence has accelerated consumer demand for 'new' products, with society's perception of the value of used goods reflected in the very low prices of second hand items on eBay[201]. Fortunately this view is not held by all customer segments. Businesses, government (e.g. defence department) and the purchasers of services remain focussed on performance and value – although some are limited by restrictive purchasing policies biased towards virgin products.

    b. **Improving the image/perceptions of 'remanufactured'**. A substantial proportion of the population associate the term 'remanufactured' with risk from quality loss. Building confidence in the term and the quality assessments, testing, and warranties that it should imply has been hindered by varying standards, a fragmented supplier base and inconsistent warranties – which in turn have encouraged unscrupulous operators who have damaged the image of remanufacturing. However, some sub-sectors offer examples of the highest quality and standards – such as the air- and spacecraft field where remanufacturing is routine. Improving perceptions is about educating customers that remanufactured products offer a sound alternative to new products.

Note that these customer perception issues to some extent can be alleviated in a business model where a customer pays for the service only, leaving the provision and up-keep of equipment to the provider. Of course equipment needs to look new, but the experience of Xerox and others have demonstrated that this can be achieved for remanufactured products.

[200] Note that in some instances disposal is desirable, such as for compostable products.
[201] This is not to deny the strong role that eBay plays in facilitating reuse of products and increasing customer perceptions of used or remanufactured goods. For example the PGA Trade it in Network 'Play it on Pledge' on eBay encourages premium re-use/product-life extension for golf products.

Figure 52: Barriers to Remanufacturing



Chapter 7: Transport Efficiency

Chapter Summary

Freight transport, worth £29.5 billion in 2011, has seen no significant improvement in efficiency over the last decade. The manufacturing sector can impact a significant proportion of this transport spend through influencing suppliers' transport choices, making decisions themselves for trans-shipping and haulage to customers and affecting downstream transportation with the weight and form of their products.

60% to 70% of goods transport in the UK is by road - the most expensive (both economically and environmentally) surface transport mode; road freight transport was therefore the focus of this discussion.

Good practice manufacturers around the world have achieved a 36% improvement in their transport greenhouse gas emissions[202] which, if adopted in the UK, would save **£650 million per annum**[203] for manufacturers, avoid **3 MtCO_2e p.a.** of greenhouse gas emissions, reduce NOx, SOx and particulates by **36%,** and improve national productivity through reduced traffic delays. The greatest savings are expected in the road transport-intensive Food, Machinery, Transport Equipment and Manufactured Articles sub-sectors.

The key barriers to achieving these transport efficiency benefits - senior management leadership, information, resources and appropriate skills - are common with Energy Efficiency. Additional barriers include legislation and the need for greater collaboration; improved infrastructure is also required to be able to quickly and efficiently switch modes.

UK Manufacturing's Freight Transport Trends

In 2011, £29.5 billion was spent on freight transport in the UK[204]. The manufacturing sector can influence a significant proportion of this spend through influencing suppliers' transport choices, changing their trans-shipping and outbound haulage practices and affecting downstream transportation costs with the weight and form of their products.

Since the 1950's, transportation of goods has increased steadily, with a flattening in the last decade and a distinct drop corresponding with the recent financial crisis (see Figure 53[205]). Modal shares have remained fairly consistent through the last four decades, although rail and water have shrunk slightly in recent years[206].

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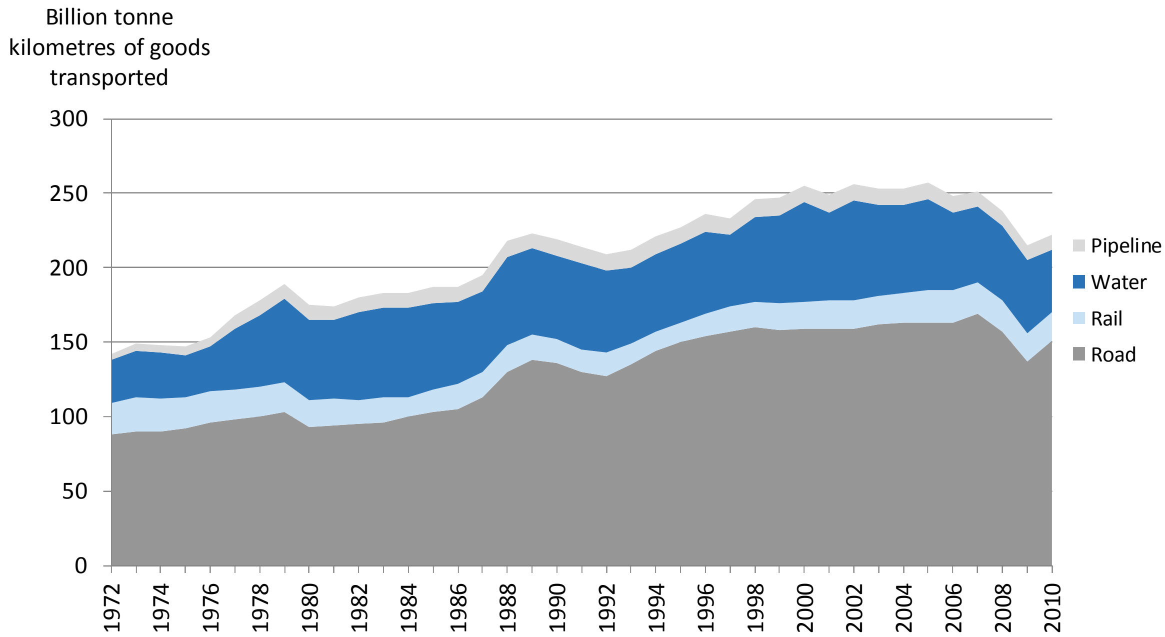
[202] Greenhouse gas emissions are used as a proxy for fuel use in this chapter of the Next Manufacturing Revolution study. This is considered reasonable given that the proportion of biofuels/lower emission fuels in UK freight transport has changed little over the period examined in this study.
[203] Based on 2011 figures.
[204] Source: Office for National Statistics, Annual Business Survey Section H: Transport and Storage, Release Date 15 Nov 2012. The figure presented excludes passenger transport, removal services, warehousing, transport support activities, cargo handling, postage, and courier services.
[205] Domestic air cargo (freight and mail) within the United Kingdom is described by the Department for Transport as "insignificant in volume compared with other modes"- Department of Transport, Transport Statistics Great Britain 2011, Notes and Definitions: Freight, p. 3.
[206] Water transport of goods includes all UK coastwise and one-port freight movements by sea, and inland waterway traffic.

Figure 53: Goods Transported in the UK



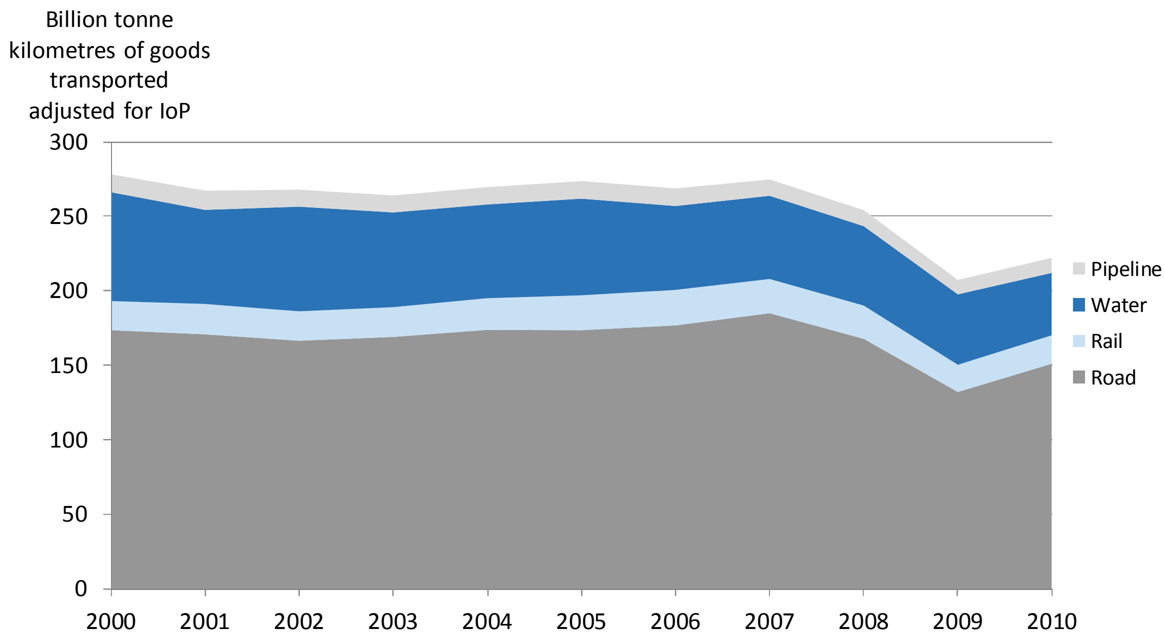
Source: Department for Transport, Transport Statistics Great Britain 2011, Table TSGB0401

To examine transport intensity in the UK (i.e. the freight transport per unit of production), the above figures were adjusted for production output[207]. Figure 54 shows that goods transport intensity has remained flat over the last decade, apart from the recent dip as a result of the global financial crisis. This suggests that there has been limited change in freight transport intensity over the last decade; post 2008 may be explained by changes in inventories by producers and customers due to the global economic slowdown[208].

[207] By dividing annual transport tonne kilometres by the corresponding annual Index of Production for the manufacturing sector, indexed to 1 in 2010. Source: Office for National Statistics, Detailed Indices of Production, 2011.

[208] For example, manufacturers building up their inventories would keep the Index of Production high, but transport figures would be low.

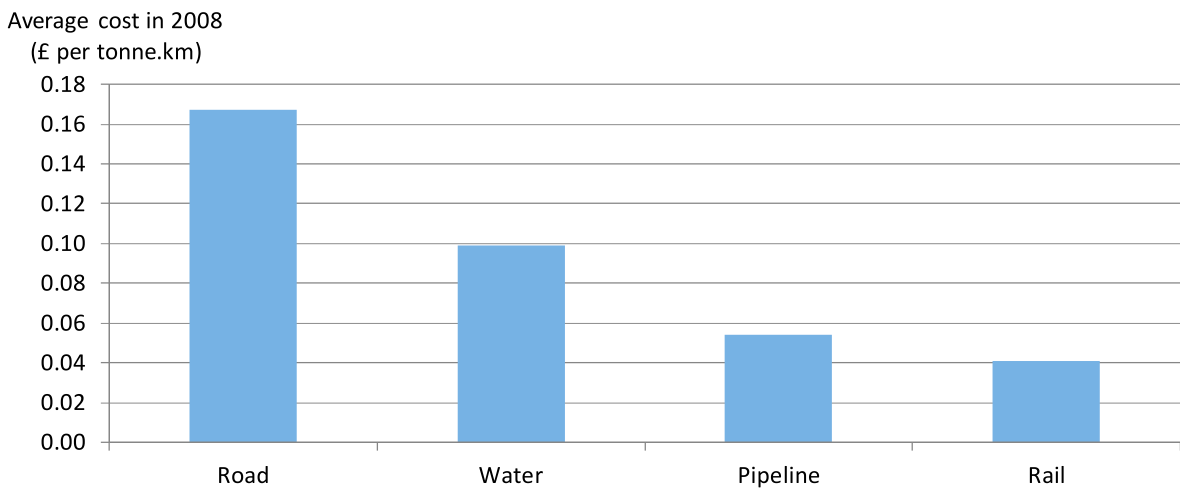
Figure 54: UK Goods Transported, Adjusted for Production, Indexed to 2010



Source: Department for Transport, Transport Statistics Great Britain 2011, Table TSGB0401; Office of National Statistics, Detailed Indices of Production, 2011

Figure 54 also shows that road transport has consistently represented between 60% and 70% share of transportation, measured by tonne kilometres. This is despite road transport being the most expensive of the surface transport modes (see Figure 55)[209].

Figure 55: Average Cost to Transport 1 tonne of Freight 1 kilometre by Mode in 2008



Note: Transport costs exclude passenger transport, removal services, warehousing, transport support activities, cargo handling, postage, and courier services.
Sources: Office for National Statistics, Annual Business Survey Section H: Transport and Storage, Release Date 15 Nov 2012; Department for Transport, Transport Statistics Great Britain 2011, Table TSGB0401

Road transport has been recognised to have the greatest external cost of the surface transport modes – i.e. cost to society not paid for by the user[210]. One of these externalities is greenhouse gas

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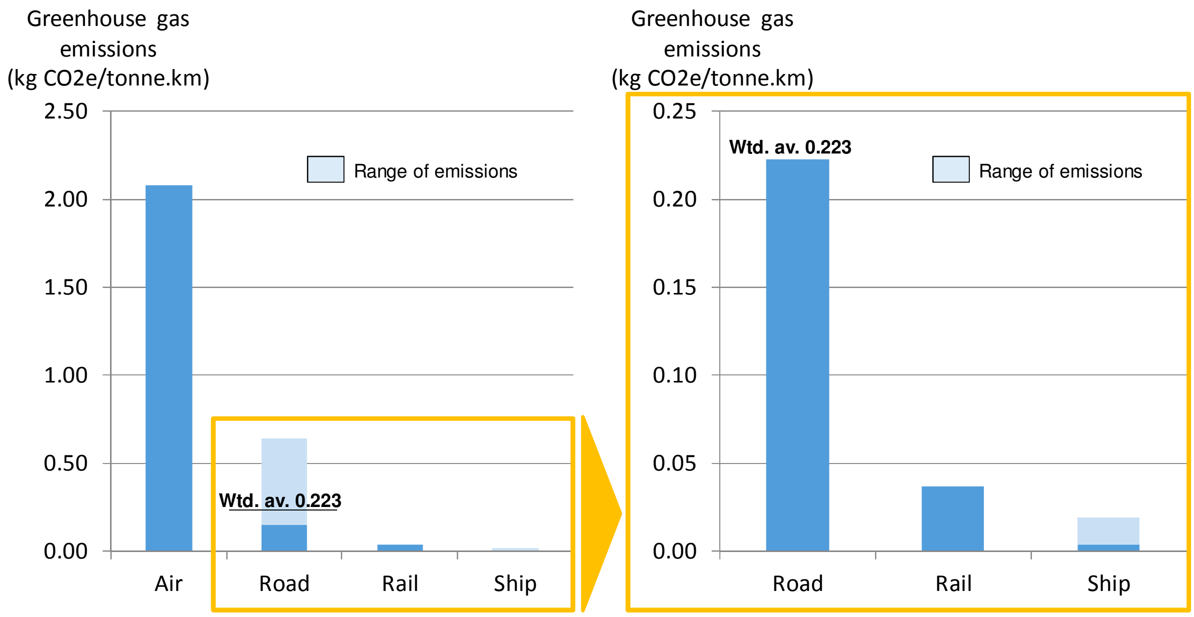
[209] Calculated by dividing the UK's 2008 freight turnover per mode by the tonne kilometres served in 2008 by each mode.
[210] See, for example, United States Government Accountability Office, Surface Freight Transportation:

emissions. Figure 56 illustrates the substantially higher emissions per tonne kilometre from road transport compared with other surface transport modes.

Figure 56: Greenhouse Gas Emissions by Freight Transport Mode, UK averages, 2008



Sources: Defra, 2011 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting, Aug 2011, Annex 7; department for Transport, Factsheet: UK Transport Greenhouse Gas Emissions, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/3085/41.pdf

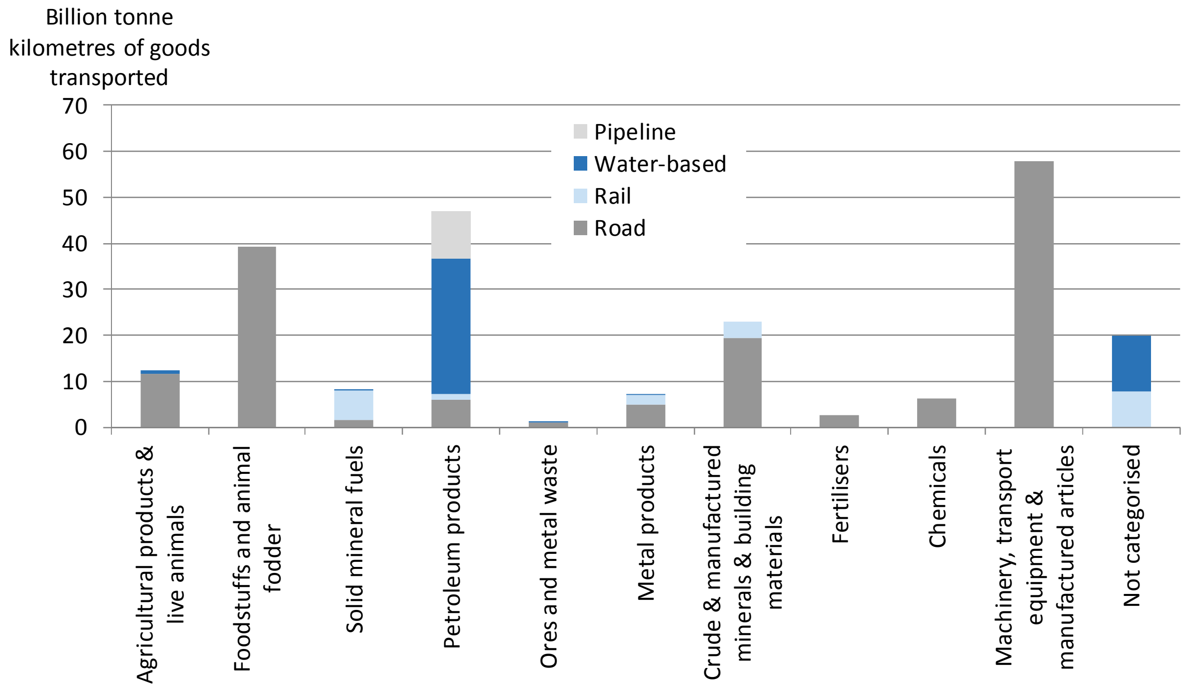
This discussion therefore focusses on road transport as a substantial opportunity for cost savings and externality/environmental impact reduction.

A Comparison of the Costs of Road, Rail, and Waterways Freight Shipments That Are Not Passed on to Consumers, Report to the Subcommittee on Select Revenue Measures, Committee on Ways and Means, House of Representatives, Jan 2011.

Transport Use by Manufacturing Sub-Sector

Examining transport use by sub-sector, Figure 57 shows the consistent use of road transport for most manufacturing sub-sectors, with water-based and pipeline transport being used almost exclusively for petroleum products[211,212]. This further supports a focus on road transport for this study.

Figure 57: 2011 UK Goods Transport by Sub-Sector



Source: Department for Transport, Transport Statistics Great Britain 2011, Table TSGB0402; Office of National Statistics, Detailed Indices of Production, 2011

Company Improvements in Transport Efficiency

Many blue chip companies have begun transport improvement efforts within the last five years and, based on transport greenhouse gas emissions (considered to be a proxy for transport efficiency improvement[213]), the leaders have been achieving 5% to 10% annual improvements (see Figure 58).

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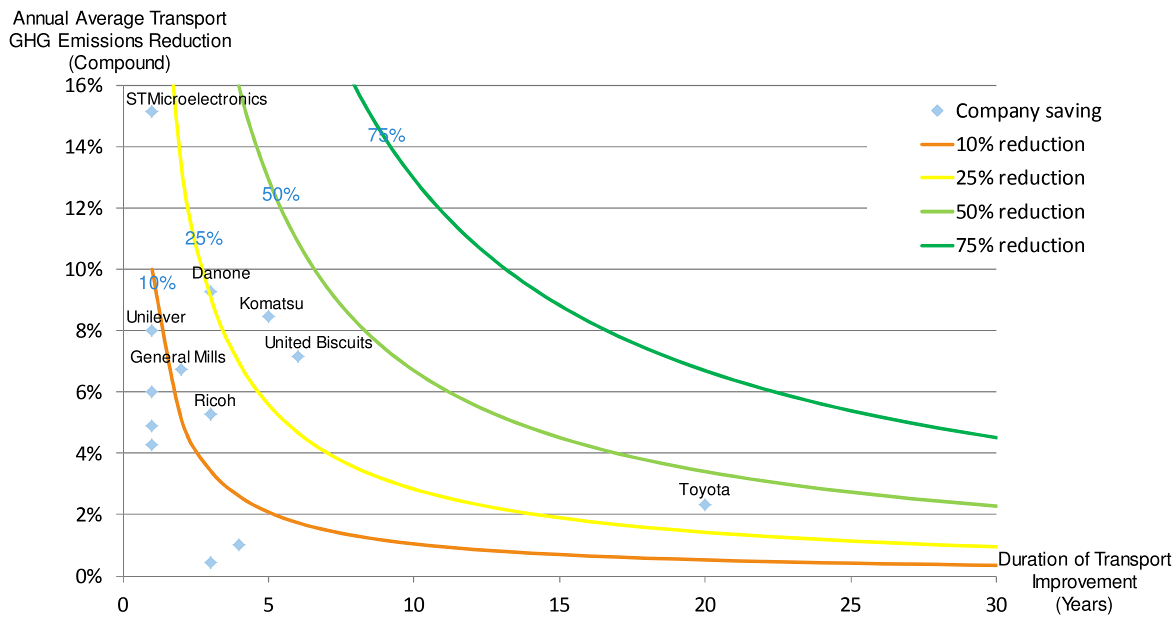
[211] The rail and water categories provided by Office of Rail Regulation and Department for Transport Port Freight Statistics do not all match the standard EC classification categories. Unmatched categories are recorded as 'Not categorised'.

[212] Several of the sub-sectors shown in the figure feed into the manufacturing sector and are therefore valid inclusions in the discussion because the manufacturing sector both pays for and is able to influence transport decisions related to these products.

[213] This is considered reasonable given that the proportion of biofuels/lower emission fuels in UK freight transport has changed little over the period examined in this study.

Figure 58: Comparison of Company Transport Greenhouse Gas Emissions Improvements

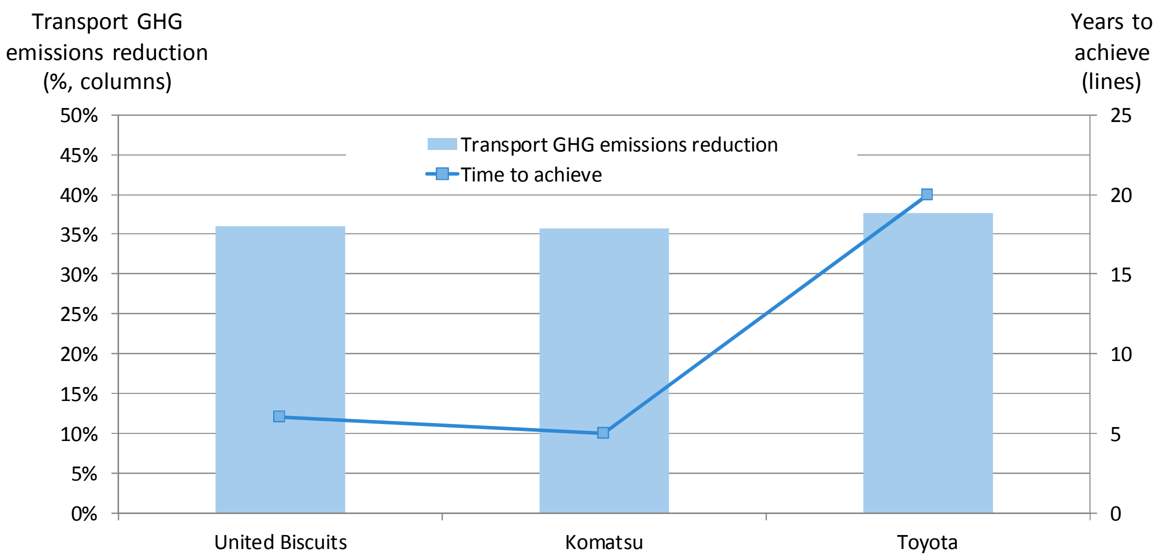


Note: Un-named datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review

Best Practice in Transport Efficiency Improvement

Three companies have achieved 36% or more total improvement in transport greenhouse gas emissions – two of these in six years or less (see Figure 59). These companies are from the manufacturing sub-sectors of Food, Beverage & Tobacco, Machinery, and Transport Equipment – which represent between them 65% of UK road freight (per Figure 57). Further, these sub-sectors mostly use road freight so their transport emissions reductions have come from improvements in or switching from, road haulage.

Figure 59: Good Practice Companies for Total Transport Greenhouse Gas Emissions Reduction



Source: Next Manufacturing Revolution analysis

Given the strict rules governing food transport in the UK to ensure hygiene and safety, United Biscuits' 36% improvement in transport emissions in just six years is impressive. With fewer regulations governing their transport activities, most of the other manufacturing sub-sectors should also be able to achieve a similar level of improvement.

How Good Practice Companies Improve their Transport Efficiency

Companies achieving substantial transport efficiency improvements have typically addressed four types of saving opportunities, each differing in ease of implementation and investment requirement. Note that savings from individual initiatives are not necessarily cumulative[214].

1. **Incremental**. These opportunities involve mostly behaviour and cultural change. Incremental opportunities are often referred to as 'quick wins' because they can be implemented quickly, do not involve capital expenditure and can create tangible savings. The most impactful incremental transport actions have been found to be:

    a. Reducing engine idling – which can improve fuel efficiency by 5%[215]
    b. Reducing highway speed – able to improve fuel efficiency by 5%[216]
    c. Driver training – found to result in a fuel efficiency gain of 4%[217]

2. **Processes and Systems**. Improvements that involve changes in processes comprise this category. Many of these savings are inexpensive in capital terms, but result in substantial savings. Major process and system opportunities to improve transport efficiency are:

    a. Automated performance monitoring with driver feedback – the Shell Fuelsave Partner telematics system, for example, measures fuel consumption, idle time, average payload, urban driving percentage, harsh braking, number of gear changes per mile, and sharp acceleration and feeds this data back to companies. It has enabled commercial transport fleet customers to cut their fuel costs by up to 10%[218].
    b. Enhanced, computerised routing and scheduling, including incorporating/optimising for real time delay data – found to create fuel savings of 3%[219].
    c. Mode switching – considered to have a potential saving in greenhouse gas emissions for the road freight sector of 1.7%[220].
    d. Increasing capacity utilisation – in 2007, 27.4% of goods vehicle kilometres in the UK were running empty and when carrying a load vehicles were found to be typically only 57% loaded as a percentage of maximum gross weight[221]. This is similar to the 2008

[214] For example, driving at lower speeds reduces the gains from aerodynamic improvements (which are proportional to the square of velocity).
[215] World Economic Forum, Repowering Transport, Project White Paper, Feb 2011; Consistent with the findings of the US EPA's Smartway program (http://www.epa.gov/smartway/publications/index)
[216] World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.
[217] World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.
[218] World Economic Forum, Repowering Transport, Project White Paper, Feb 2011, p. 52.
[219] World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.
[220] World Economic Forum, Supply Chain Decarbonisation, Jan 2009, pp. 33-39. Calculated on a global basis.
[221] Allen, J. and Browne, M. Road freight transport and sustainability in Britain 1984-2007, Transport Studies Department University of Westminster, Sep 2010, pp. 28, 23; Defra/DECC's Greenhouse Gas Conversion Factors for Company Reporting, Aug 2011, Annex 7 shows capacity utilisation rates for trucks between 37% and 61% by weight depending on the type of truck. Note that statistics presented in the Department for Transport, Primary Distribution Benchmarking Survey, 2009 (found at

figures for EU of 24% running empty and 57% loaded as a percentage of maximum gross weight[222]. Government figures suggest that these rates are similar for the US[223]. Avoided empty running was found to save 18% of fuel for the company Kronospan through utilising a quarter of its empty return trips[224].

e. Off-peak and evening deliveries – to avoid congestion and increase vehicle utilisation.
f. Sourcing raw materials locally, including increasing recycled content – reducing transport distances.

3. **Structural Change**. Where new equipment or production/distribution redesign is involved, this is structural change for a company, often involving capex. Typical areas of opportunity in the road freight sector from structural change are:

   a. Truck engine improvement – substantial gains are considered to be available from improving the efficiency of conventional engines (worth an estimated 18% saving in fuel[225]), as well as switching to hybrid engines (worth up to 25% in fuel saving[226]).
   b. Non-engine mechanical changes to trucks – for example transmission improvements (worth a 4% fuel saving[227]).
   c. Truck body adjustments – changes to the design of truck exteriors can have a substantial impact on fuel efficiency. These include improving aerodynamics (worth up to 14% of fuel use[228,229]), longer semi-trailers (a two metre increase in length would increase payload volume by 15%), low rolling resistance tyres (saving 4% of fuel[230]), automatic tyre inflation (worth a 1% saving in fuel[231]) and light-weighting (considered to save 1% of fuel[232]).[233]
   d. Production and distribution hub number and locations (including urban consolidation centres) – enabling improved capacity utilisation and minimising distances travelled. Unilever have announced a project to change their network of transport hubs throughout Europe, which they expect, when combined with additional supply chain management technologies, will reduce truck journeys in Europe by 200 million

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http://www.slideshare.net/xiao312/fbp1107-primary-distribution-benchmarking-survey) indicate higher vehicle fill at 82% of gross vehicle weight and lower average empty running of 13%. However, these DoT figures were self-reported by self-selected trucking companies and backhauling packaging was not counted as empty running in that survey.

222 World Economic Forum, Supply Chain Decarbonisation, Jan 2009, p. 19.

223 King, citing U.S. Department of Transportation statistics, notes that in the U.S. average truck-trailer loads are less than 60% full, and between 20% and 25% of trips is made with an empty trailer. Source: King, B. "'Physical Internet' for Logistics Could Boost U.S. Profits $100 Billion, Cut Emissions 33%", Sustainable Brands, 4 Jan 2013, http://www.sustainablebrands.com/news_and_views/articles/physical-internet-logistics-could-boost-us-profits-100-billion-cut?utm_source=newsletter&utm_medium=businessweekly&utm_campaign=jan7

224 Welsh Assembly Government, Achieving Supply Chain Efficiency through Backloading and Multi-modal Transport, Aug 2010.

225 World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.

226 World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.

227 World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.

228 World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.

229 Note that aerodynamic improvements are only of significant value at higher speeds (e.g. above 80km/hr) because aero resistance is proportional to the square of the velocity.

230 World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.

231 World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.

232 World Economic Forum, Repowering Transport, Project White Paper, Feb 2011.

233 Note that 3a, 3b and 3c usually occur as part of vehicle selection, with the changes themselves designed into the vehicles by truck manufacturers.

kilometres a year, including 23 million kilometres a year in the UK[234], from the end of 2014. This optimisation can be extended to incorporate the freight requirements of multiple companies (for example, supermarkets agreeing to share vehicle space when picking up from producers or when delivering to their supermarkets).

e. Reduce congestion – avoiding unnecessary idling and frequent acceleration and braking related to traffic congestion by reducing that congestion by 27% (a figure considered achievable by the World Economic Forum) is estimated to reduce road freight transport greenhouse gas emissions by 1.6%[235].

4. **Core Redesign**. Altering the core of how a business operates can lead to the greatest savings. The cost and payback periods of core changes can be longer than other saving opportunities, and such ideas can be slow and difficult to implement in a company resistant to change. Examples of core redesign opportunities to improve transport efficiency are:

    a. Concentrating product – reducing its bulk and weight. Consider the example of laundry powder and liquids which have doubled their concentration in some countries over the last decade.
    b. Better packaging design for load optimisation – increasing capacity utilisation rates, especially for awkward/delicate cargoes such as flowers.
    c. Light-weighting product – reducing the weight of products and therefore enabling greater volume to be transported for the same load weight capacity on a truck and reducing the energy required for air freight.
    d. Light-weighting and reducing packaging – this saves not only on transport from factory to customers, but also on transport of post-consumer material to disposal/recycling.

Examples for a range of manufacturing sub-sectors are presented on the Next Manufacturing Revolution website www.nextmanufacturingrevolution.org under the 'Case Studies' tab.

The Full Potential of Road Freight Efficiency for the UK

The total turnover of the road freight transport sub-sector in 2011 was £22.5 billion[236].

Observed best practice for improvement in transport greenhouse gas emissions is 36% (see Figure 59). To convert this to a potential cost saving for manufacturing-related transport, it has been applied to road transport only – which is the majority of the freight transport in the UK and the vast majority for the sectors in which the best practice companies sit[237].

[234] Murray, J. "Unilever reveals roadmap to cut fleet journeys by 200 million kilometres", BusinessGreen, 10 Oct 2012, http://www.businessgreen.com/bg/news/2215770/unilever-reveals-roadmap-to-cut-fleet-journeys-by-200-million-kilometres.

[235] World Economic Forum, Supply Chain Decarbonisation, Jan 2009, pp. 33-39. Calculated on a global basis.

[236] Source: Office for National Statistics, Annual Business Survey Section H: Transport and Storage, Release Date 15 Nov 2012. The figure presented excludes passenger transport, removal services, warehousing, transport support activities, cargo handling, postage, and courier services.

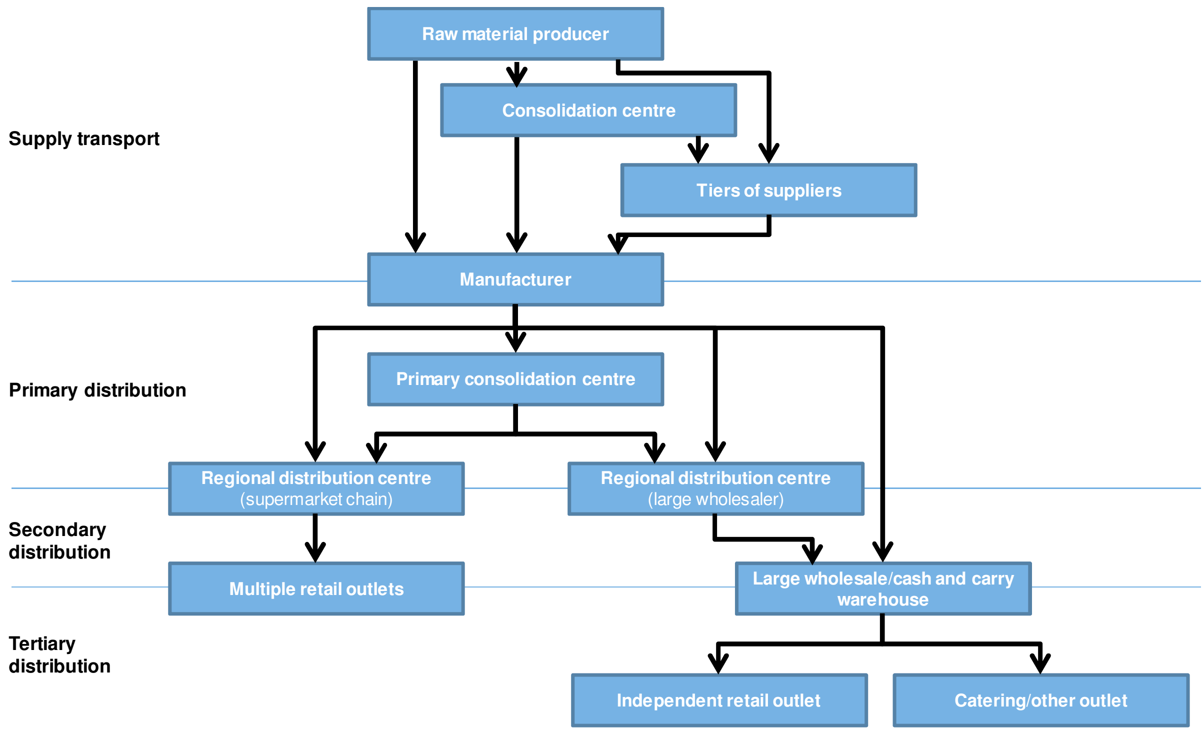
[237] This is likely to produce an underestimate of the full potential of the saving, however this conservative approach allows for possible differences in greenhouse gas emissions savings across the various transport modes (which is not known) by the best practice companies.

Greenhouse gas emissions relate to fuel usage; expenditure on fuel represents 32% of the turnover of the road transport sector[238].

Therefore the economic value of improving road freight related to the transport of goods by 36% is £2.6 billion per annum, based on 2011 figures[239].

However, this figure is greater than the saving for manufacturers – the subject of this study – because it includes road freight used by all parts of the goods supply chain. Figure 60 illustrates the four transport stages across the supply chain for food and fast moving consumer goods (FMCG). Manufacturers can only directly influence the Supply Transport stage (through working with suppliers or otherwise using their purchasing power to influence transport practices) and Primary Distribution (where this is controlled by the manufacturer and not the retailer). Given that some Primary Distribution is controlled by retailers and that Secondary and Tertiary Distribution (controlled by retailers) can involve the movement of smaller loads to a greater number of customers/destinations, it has been estimated that Supply Transport and Primary Distribution controlled by manufacturers together account for one quarter of road freight transport in manufactured goods' supply chain[240].

Figure 60: Transport through the supply chain for food and FMCG goods



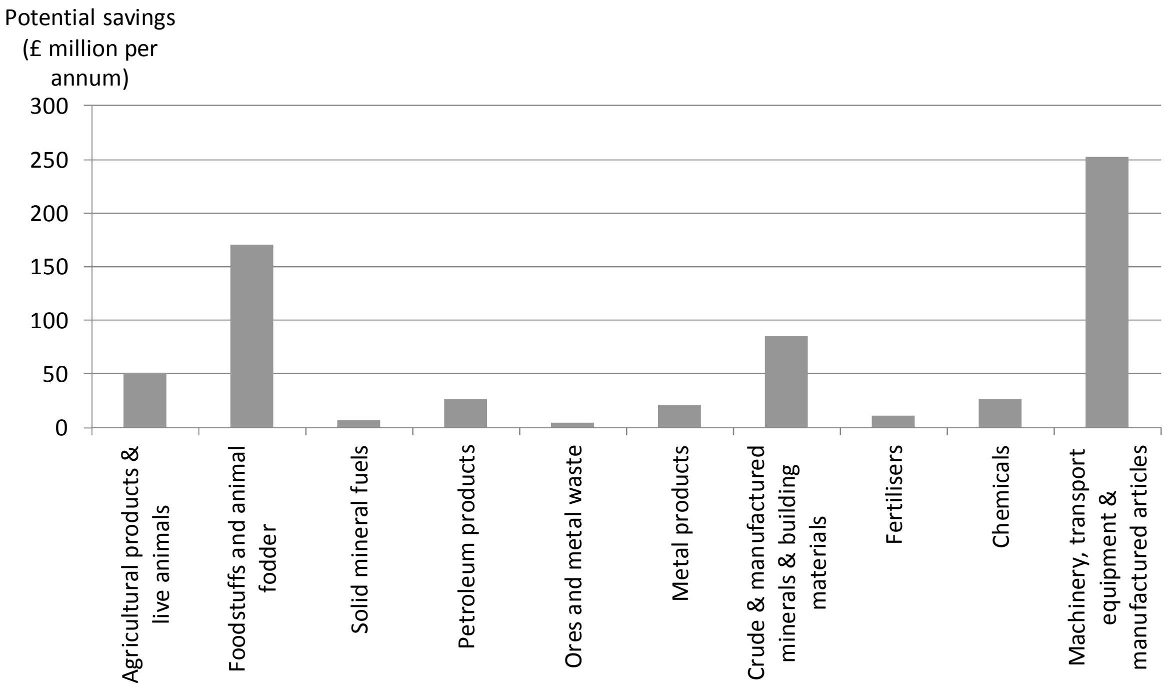
Source: Lavery Pennell analysis; McKinnon, A. Yongli Ge, Leuchars, D., Analysis of Transport Efficiency in the UK Food Supply Chain: Full Report of the 2002 Key Performance Indicator Survey, Heriot-Watt University, Apr 2003, p. 11.

[238] Fuel is 40% of operating costs (source: Freight Transport Association, The Logistics Report 2012, p. 19), and operating costs are 80% of the turnover of the road freight sector (source: Office for National Statistics, Annual Business Survey Section H: Transport and Storage, Release Date 15 Nov 2012).
[239] £22.5bln x 32% fuel cost x 36% improvement.
[240] Estimate made in consultation with the Operations Management expertise at the University of Warwick, Mar 2013.

The saving opportunity for UK manufacturers for road freight transport is therefore estimated to be **£650 million per annum**, based on 2011 figures[241].

Apportioning these savings to sub-sectors by tonne-kilometres of road freight (as per Figure 57) results in an estimate of the opportunity for each sub-sector (see Figure 61). Note that this is a high level approximation because the vehicle mix and load types vary between sub-sectors as dictated by the different cargo types.

Figure 61: Approximate Road Haulage Saving Opportunity for UK Manufacturers by Sub-Sector



Source: Next Manufacturing Revolution analysis.

The magnitude of savings presented above are supported by the literature:

- The estimates of fuel savings discussed in the good practice actions section above can be multiplied through to estimate the potential savings by type of saving and in combination (see Figure 62). Note that only the actions directly applied to vehicles and their drivers using existing mainstream technologies are included here.

Figure 62: Magnitude of Road Transport Savings Actions

Type of Saving	Actions	Estimated Fuel Saving
Incremental	Reduce engine idling Driver training *Combined Incremental impact*	5% 4% 8.8%
Processes & systems	Enhanced, computerised routing and scheduling	3%

[241] That is, one quarter of £2.6 billion.

Structural	Engine efficiency improvement Transmission improvements Aerodynamics improvements Low rolling resistance tyres Automatic tyre inflation Light-weighting of trucks *Combined Structural impact*	18% 4% 14% 4% 1% 1% 36.3%
Core redesign	Not related to trucks or driver behaviour	-
TOTAL	**Combined impact of changing trucks and driver behaviour with existing technology**	**44%**

This 44% impact is slightly higher than the best practice figure used in this study of 36%. It does not, however, include the savings available from reducing highway speed, improving capacity utilisation, local sourcing, hybrid engines, longer vehicles, production and distribution hub optimisation, concentrating product, or light-weighting of product and packaging. This suggests that substantial potential exists beyond the current observed best practice; although the current capital cost and payback period of some actions may limit the take-up of some actions in the short term.

- The U.S. Department of Transport cites substantial savings opportunities, although they are more conservative than the figures calculated in this report:

> "Heavy-duty trucks retrofitted to use aerodynamic fairings, trailer side skirts, low-rolling resistance tires, aluminium wheels, and planar boat tails can reduce per truck GHG emissions by 10 to 15%. For new trucks, combined powertrain and resistance reduction technologies are estimated to reduce per vehicle emissions by 10 to 30% in 2030."[242]

- The King Review, which looked at emissions from cars (mechanically similar to trucks and at a similar point in their evolution), showed that a 30% saving in greenhouse gas emissions is reasonable at an acceptable up-front cost:

> "Technology that can reduce CO_2 emissions per car by 30% (on a like-for-like basis) is already close to market and could be standard within 5 to 10 years. Despite the likely vehicle cost increases (estimated at £1,000 to £1,500 per new vehicle), many of these changes are likely to represent good economics to the purchaser, as a result of their impact on fuel economy."[243]

- Recent trade literature supports the view that there is a substantial opportunity in the UK:

> "The reality is that many manufacturers don't really know where to start. Very few of the manufacturing companies that we work with have tackled the crucial first step of measuring their transport efficiency accurately. Yet it is only by identifying where waste occurs that it can be effectively managed out of the process ..."[244]

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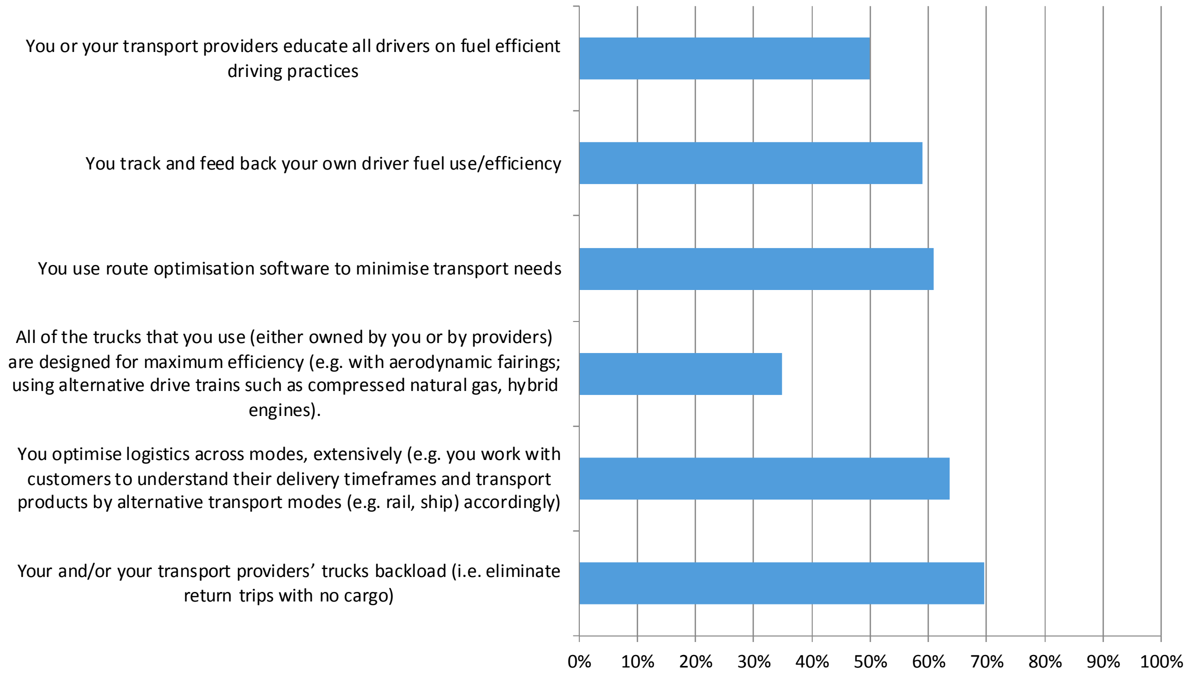
[242] U.S. Department of Transportation, Transportation's Role in Reducing U.S. Greenhouse Gas Emissions, Volume 1: Synthesis Report, Report to Congress, Apr 2010, p. ES-5.
[243] King, J. The King Review of Low-Carbon Cars, Part I: the potential for CO_2 reduction, HM Treasury, Oct 2007, p. 5.
[244] Fawkes, T., A transport of delight: Reducing costs in the manufacturing supply chain, The Manufacturer, 16 Mar 2012.

The Next Manufacturing Revolution survey[245] results (see Figure 63) suggest substantial improvement opportunities in transport efficiency, consistent with the broader findings of this study. However, the rates of take-up of the examined initiatives by respondents are much higher than the above literature would suggest, consistent with a sample bias given the good sustainability track records of survey participants. For example, the 70% figure of companies who have eliminated empty trips is inconsistent with the EU average of 24% empty vehicles, because this would mean that almost all of the 30% who answered "No" to the last question are running empty all of the time - clearly not the case as manufacturers only use transport when they need it.

Figure 63: Results of Next Manufacturing Revolution Survey Questions Regarding Transport Efficiency: Percentage of Respondents Agreeing with the Statements[246]



Reducing greenhouse gas emissions also benefits the environment. Road freight transport in the UK for Supply Transport and Primary Distribution in 2010 generated 8.4MtCO_2e in greenhouse gas emissions[247]. A 36% improvement to best practice represents a saving related to manufacturing of **3 MtCO_2e p.a.**[248]. A similar proportion (i.e. 36%) saving is expected in NOx, SOx and particulates from road freight vehicles.

Reduction in the number of vehicle trips has a range of social benefits, including less taxpayer spending on roads and highways and less road congestion – saving citizen and business time, productivity and fuel cost/waste from being delayed by traffic.

[245] For details of the survey see Appendix 3.
[246] Note that the survey only gave the response options of 'yes' and 'no'.
[247] Calculated as 150.5 billion t-kms (Figure 53) x 25% of freight trips for Supply Transport and Primary Distribution x 0.223 kg CO_2e/t-km (Figure 56).
[248] Calculated as 150.5 billion t-kms (Figure 53) x 25% of freight trips x 0.223 kg CO_2e/t-km (Figure 56) x 36% best practice saving.

Barriers to the Adoption of Transport Efficiency

The same barriers to energy efficiency were observed[249], which is expected given the similar nature of many of the improvement opportunities available[250]:

1. **Senior management leadership** to drive action at all levels and in all parts of an organisation – necessary to overcome inertia and ingrained behavioural/cultural norms and commit the necessary resources
2. **Information** on/awareness of the opportunities. An additional information barrier for transport efficiency is the lack of transparency of costs for a number of modes[251]. This makes it difficult for manufacturers to optimise their logistics for that mode and for investors/government to identify bottlenecks requiring investment.
3. **Resources** to apply to the opportunities requiring investment
4. The **mix of skills** required to drive change, including engineering/technical know-how, commercial skills, change management capabilities and systems optimisation expertise.

In addition, three further barriers exist:

5. **Infrastructure.** As an example, mode switching cannot occur without suitable infrastructure, e.g. to trans-ship between road and canal quickly.

6. **Legal, specifically legislation.** A number of current laws are hampering efforts to improve transport efficiency. For example, current health and safety legislation prevents waste being transported on the same vehicles as food. This can act as a deterrent throughout the food and beverage supply chain from returning materials and packaging to upstream suppliers. However, with persistence, ingenuity and collaboration with regulating bodies, best practice companies like The Co-Operative have managed to reduce their waste transportation by 95% by back-loading waste, using dividers, cages and covers to avoid contamination.

7. **Collaboration**. Working together with internal teams (sales, production planning and logistics), customers and peers is necessary to access a number of potential savings opportunities. For example, mode switching, capacity utilisation improvement (including back-loading) and off-peak deliveries can be substantially improved by:

    a. ***Managing delivery time requirements internally and with customers***. Logistics teams are under pressure to deliver shipments as soon as possible – sometimes due to just-in-time requirements of customers, sometimes due to last minute completion of orders, and sometimes due to the keenness of sales staff to have product with customers as soon as possible in an effort to appear to be responsive to customer needs. However, better planning/forecasting[252] and ascertaining the true delivery requirements of customers can substantially improve capacity

[249] Sources include: Next Manufacturing Revolution interviews with transport organisations; Department for Transport, Primary Distribution Benchmarking Survey, 2009; World Economic Forum, Repowering Transport, Project White Paper, Feb 2011; Fawkes, T., A transport of delight: Reducing costs in the manufacturing supply chain, The Manufacturer, 16 Mar 2012; U.S. Department of Transportation, Transportation's Role in Reducing U.S. Greenhouse Gas Emissions, Volume 1: Synthesis Report, Report to Congress, Apr 2010.
[250] Refer to the Energy Efficiency chapter for a more detailed discussion.
[251] For example, one peer reviewer noted that their logistics division had been quoted rail freight costs higher than for road with no explanation or breakdown.
[252] By the manufacturer and by the customer, and most importantly the two working together to design the optimal integrated solution.

utilisation by allowing load optimisation/combination and facilitate the use of slower but lower cost/impact transport modes.

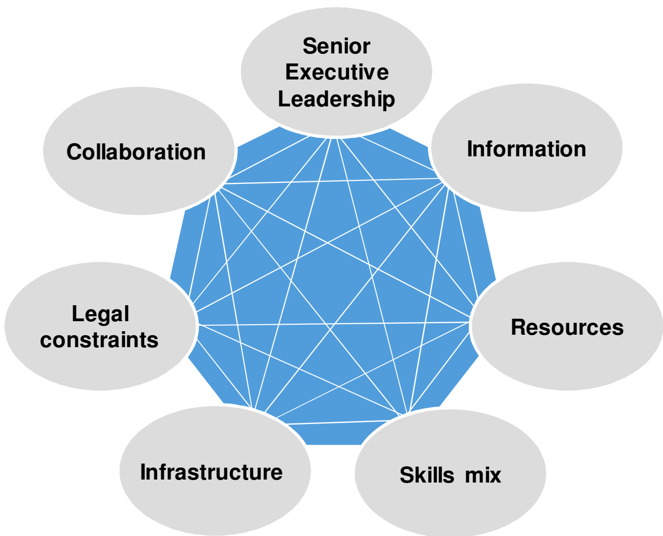
Interface, for example, work with their customers to understand true delivery timing requirements. This has enabled them to use canals and rail in Europe to reduce their transport costs and environmental impacts.

b. ***Peer co-operation***. Working with other companies with similar transport requirements can reduce empty running and improve vehicle utilisation. However, collaboration requires the alignment of otherwise independent businesses and equitable sharing of the savings. These issues have been overcome through sophisticated transport management systems, often managed by an independent transport company who is able to:
   - Determine loading/delivery times to maximise efficiency
   - Ensure service level and process alignment
   - Take a fair approach to sharing the savings
   - Maintain rigorous confidentiality to protect confidential logistics practices of each party.

   Cash Services Australia is an example of the use of an independent third party to successfully manage the logistics of competing companies. They manage the cash counting and transport for Australia's largest banks and a range of retailers – optimising collection and replenishment operations while maintaining confidentiality around the cash stocking practices and cash volumes of each client. The cost savings are substantial - for example avoiding separate trips to stock automatic teller machines that sit side-by-side in a shopping centre.

Of course customer collaboration is also required for the successful redesign of products and packaging.

Figure 64: Transport Efficiency Barriers



Chapter 8: Supply Chain Collaboration

Chapter Summary

Supply chain collaboration is a mechanism for assisting to achieve cost and environmental footprint reductions throughout an organisation's supply chain. Such collaboration can unlock savings in energy, transport, packaging, materials and waste within domestic manufacturing suppliers (discussed and quantified in other chapters of this study). It can also unlock savings from other types of suppliers, including overseas manufacturers, agricultural suppliers and utility providers.

Supplier collaboration changes the relationship between companies and their suppliers. Historically, purchasing departments within UK manufacturers have concentrated on reducing the price per unit of purchased goods, services and materials in a win-lose (adversarial) negotiation. A more collaborative approach to supplier interaction is yielding significant benefits for pioneering manufacturers who are optimising across multiple steps in their supply chains (vertical collaboration) and across a breadth of suppliers (horizontal collaboration) – unlocking system-wide synergies not accessible with the traditional adversarial negotiation approach.

There is an extensive range of collaboration opportunities available. Beyond the savings calculated in previous chapters that can be accessed through working closer with suppliers, five additional opportunities were valued in this section[253]. Based on observed good practice, these were conservatively estimated to be worth **£390 million p.a.** to UK manufacturers and reduce greenhouse gas emissions by **1.7MtCO_2e p.a.**

Companies that are leading the way in accessing these benefits have done so through senior executive commitment to building collaborative relationships, combined with investment in the necessary resources.

However, a number of barriers are hampering wider adoption of supplier collaboration. These include:

- Senior executive leadership within both suppliers and customers to lead the culture change necessary to build better trust and commit the resources and data necessary to collaboratively engage with suppliers/customers.
- A lack of information on opportunities due to limited availability of good practice case studies, as well as a lack of transparency through supply chains preventing quantification of specific opportunities.
- Resources to drive the investment required to unlock supply chain opportunities and address the trust and logistical difficulties of having frequent and deep conversations with a large number of suppliers.
- Limited capacity and capabilities in purchasing teams to provide the facilitation, communication and data management required for collaborative supplier relationships – as well as the technical, commercial, change management and systems optimisation skills necessary to unlock improvement opportunities.
- Utility rules preventing manufacturers from accessing the potential of demand reduction.
- The need to trust counterparties who often have been adversarial in prior negotiations.

[253] The five opportunities examined were energy efficiency and transport efficiency related to overseas manufacturers, energy & water efficiency and land productivity for agricultural suppliers and electricity demand reduction.

Introducing Supply Chain Collaboration

Historically, supply chain interactions have been considered in the context of 'supply chain management'. As the term suggests, the resulting relationships with suppliers have been 'managed' and transactional with a focus on optimising cost, inventory and service level.

Recently, however, a wider range of influences have prompted some companies to revisit their supplier relationships. These influences include:

- Volatile demand, requiring more responsiveness in the supply chain at the same time as inventories are being driven down to conserve cash
- Increasing commodity prices and resource constraints prompting companies to look for new cost savings
- Customer (and other stakeholder) demands for increased transparency and corporate responsibility from retailers and manufacturers throughout their entire supply chain

For example, Tesco plc recently announced a major change in the way they do business to incorporate a new core value: 'Using our scale for Good.' Central to this is how they work in partnership with suppliers to deliver the innovation needed to meet customer needs and make a difference to society. Tesco have set up an online supplier community to support collaboration, called the Tesco Knowledge Hub[254] that has as its goal a 30% carbon reduction in products sold by Tesco[255]. The majority of Tesco's top 1,000 suppliers are active members of this community.

The resulting relationships differ from a traditional transactional approach in several ways:

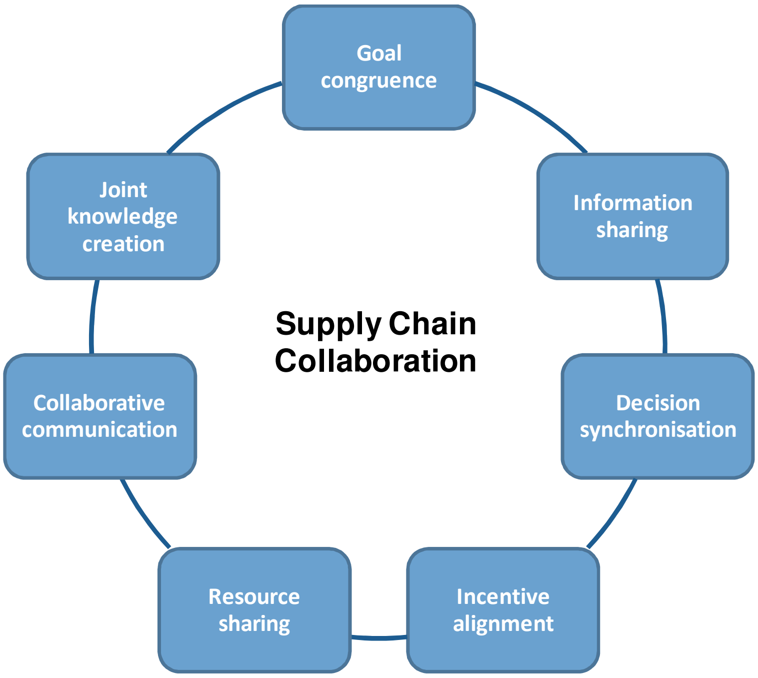
1. The scope for resource efficiencies is extended to encompass **synergies along the supply chain** as well as **synergies between parallel supply chains**.
2. The range of **parameters** being optimised has increased from cost, inventory and service level to include social and environmental performance, risk management, innovation and continuous improvement trajectories.
3. The nature of the supplier-customer **relationship** has itself changed from adversarial to partnering – recognising that a system-optimised solution will be better than the sum of optimised sub-units.
4. The purpose, nature and effectiveness of partnerships between customer and suppliers is being transformed through the use of **communications and collaboration technologies.**

These differences enable win-win solutions to be developed instead of narrowly focussing on a few metrics to commoditise products and force a win-lose negotiation, usually won by the buyer with their greater power, and which can damage the viability of the less powerful party in the negotiation.

Successful supply chain collaboration has been defined in terms of seven elements (see Figure 65)[256].

[254] Established in partnership with 2degrees.
[255] Source: The Tesco Knowledge Hub, c. 2012, http://www.2degreesnetwork.com/groups/supply-chain/resources/big-plans-tesco-knowledge-hub-2degrees/ [accessed 6 Jun 2013].
[256] Sources: Lee, H., The Triple-A Supply Chains, Harvard Business Review, Oct 2004, pp. 102-112; Cao, M., Zhang, Q., Vonderembse, M. A., Ragu-Nathan, T. S., Achieving Collaborative Advantage and Firm Performance through Supply Chain Collaboration, Proceedings of the 39th Annual Meeting of the Decision Sciences Institute, 2008, pp. 2851-2856. http://www.decisionsciences.org/Proceedings/DSI2008/docs/285-3525.pdf.

Figure 65: Seven Elements of Supply Chain Collaboration



Source: Cao, M., Zhang, Q., Vonderembse, M. A., Ragu-Nathan, T. S., Achieving Collaborative Advantage and Firm Performance through Supply Chain Collaboration, Proceedings of the 39th Annual Meeting of the Decision Sciences Institute, 2008, pp. 2851-2856. http://www.decisionsciences.org/Proceedings/DSI2008/docs/285-3525.pdf

This more collaborative supply chain approach is unlocking additional value for both suppliers and customers – including resource productivity, improved innovation, risk reduction and brand enhancement. These are discussed in detail below.

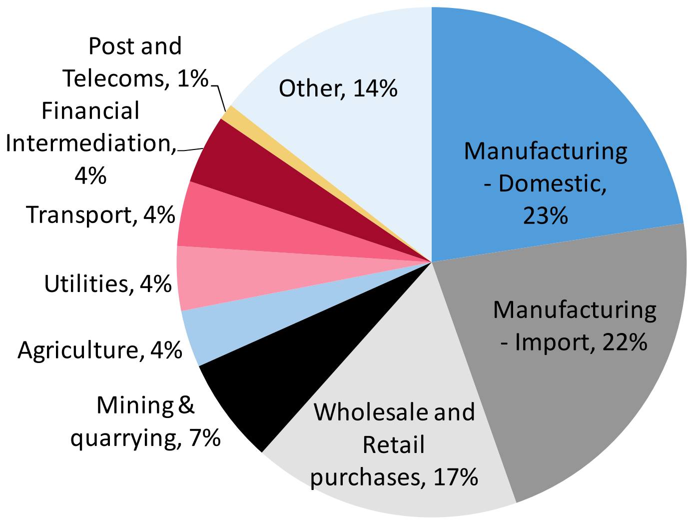
Supply chain collaboration can be considered as an area of resource productivity in its own right due to savings beyond the other six topics examined in this study. It can also be used as a mechanism for assisting to reduce costs throughout an organisation's supply chain – an approach that can access the opportunities described in all chapters of this study.

UK Manufacturing Supply Chain Flows

In 2011, UK manufacturers spent **£340 billion** on goods, services and materials[257]. These non-labour inputs were dominated by flows from other domestic manufacturers (23%), offshore manufacturers (22%), and wholesale and retail (17%) which comprise mostly manufactured goods. Secondary resource inputs were from mining & quarrying (7%), agriculture (4%), utilities (4%) and transport (4%) (see Figure 66). These inputs offer opportunities for improvement through supply chain collaboration – a total of 81% of spend on goods, services and materials amounting to £278 billion in 2011.

[257] Source: Office for National Statistics, Annual Business Survey, Section C: Manufacturing, Release date 15 Nov 2012.

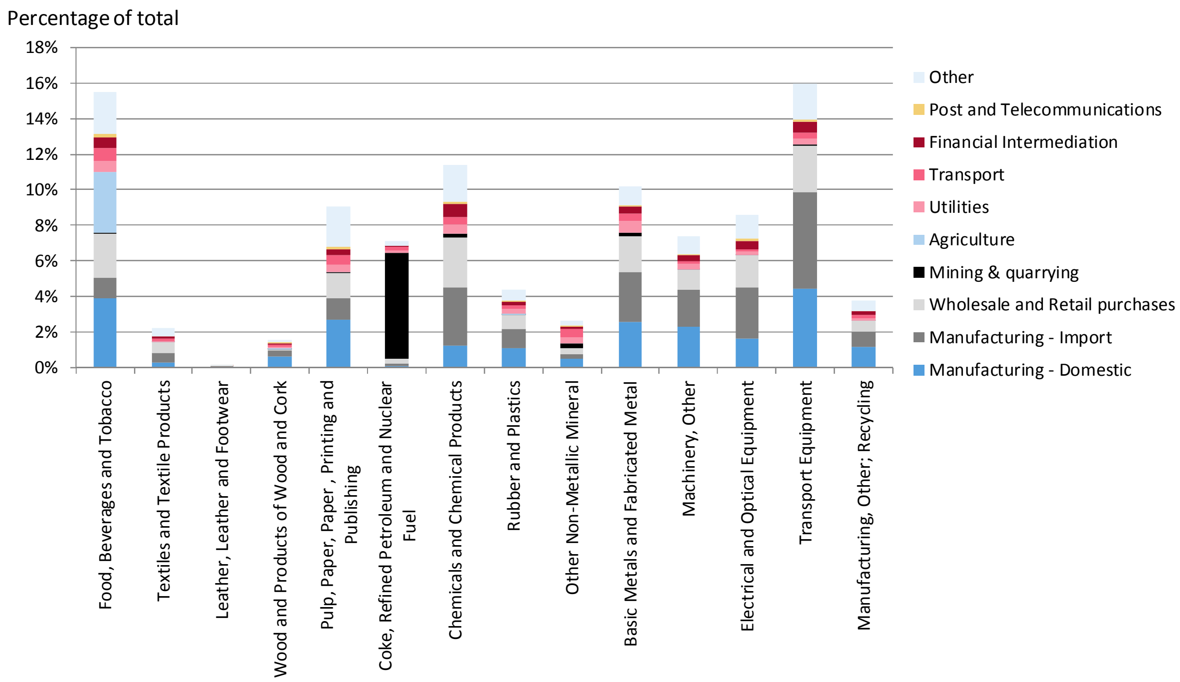
Figure 66: UK Non-Labour Manufacturing Inputs, 2009



Note: 'Other' includes renting of equipment, purchasing and maintenance of motor vehicles, hospitality, real estate, and construction.
Source: World Input Output Database, http://www.wiod.org/database/nat_suts.htm

Figure 67 shows that these inputs service mainly eight sub-sectors. One of these (Coke, Refined Petroleum and Nuclear Fuel) is dominated by and absorbs most of the mining and quarrying materials used in manufacturing.

Figure 67: Flow of Goods, Services and Materials into UK Manufacturing Sub-Sectors by Percentage of Total, 2009



Note: 'Other' includes renting of equipment, purchasing and maintenance of motor vehicles, hospitality, real estate, and construction.
Source: World Input Output Database, http://www.wiod.org/database/nat_suts.htm

The Benefits of Supply Chain Collaboration

Supply chain collaboration unlocks two major areas of value:

1. Optimisation of activities between supplier and customer, where an optimised combined system is more efficient than specific supply chain steps, optimised individually. This is referred to as 'Vertical Collaboration', since it integrates across steps in the value chain.
2. Improved scale through integrating the activities of multiple suppliers. This represents 'Horizontal Collaboration', since it involves multiple suppliers in parallel.

Significantly, the value created often benefits both suppliers and customers as savings are shared and the economic success of both parties is enhanced, reducing risks and encouraging even greater collaboration. This win-win synergy was described by Michael Porter as 'Shared Value'[258].

Figure 68 presents the specific sources of value for the two areas noted above, including how the value is created for customers.

Figure 68: Benefits of Supply Chain Collaboration

Types of value	Specific sources of value	Examples	How Value is Created for Customers					
			Revenue increase	Cost saving	Inventory reduction	Risk reduction	Brand enhancement	Customer service improvement
Vertical Collaboration (optimising across supplier and customer)	Demand planning & fulfilment improvement	• Traditional Supply Chain Management		✓	✓			✓
	Cross-boundary optimisation	• Improved understanding of needs • Process innovation		✓	✓	✓		✓
	Product innovation	• Identification and development of new solutions	✓	✓			✓	✓
	Reintegration of waste	• Recycling of process waste • Remanufacturing of products post-consumer		✓			✓	
	Risk reduction	• Security of supply (e.g. by improving the viability of suppliers) • Reduced price volatility (e.g. by long term, lower priced contracts)		✓	✓	✓		
	Confidence to invest (i.e. secured future)	• Supplier investing in new equipment and products • Customer investing in supplier		✓				
	Improved social and environmental performance	• Improved transmission of corporate responsibility expectations leading to reduced environmental footprint		✓		✓	✓	
Horizontal Collaboration (scale of activity across multiple suppliers)	Scale purchasing	• Scale purchasing for all suppliers		✓			✓	
	Best practice sharing	• Best practice information sharing		✓		✓		
	Investment benefitting all suppliers	• Investment in R&D to improve supplier productivity • Technology investment and pull-through		✓			✓	
	Collaboration amongst suppliers	• Transport sharing		✓				

Illustrating each of the sources of value by way of examples:

> **Cross-boundary optimisation**: A study of the upstream energy usage for Walkers Crisps (owned by PepsiCo) identified that substantial energy was being used by potato farmers humidifying their produce in order to maximise their revenues because they were paid by weight. Walkers then spent 10% of their energy in the potato frying step removing this

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[258] See Porter, M. E., Kramer, M. R., 'Creating Shared Value', Harvard Business Review, Jan-Feb 2011.

additional water. Changing the contract eliminated this misalignment, saving the supply chain £1.2 million p.a.[259]

Product Innovation: BASF developed a new resin for the window trim for Ford's Fusion model. The resin does not need to be painted so avoids the window trim having to be sent to a different factory for painting, halving the cost of the part, reducing greenhouse gas emissions and eliminating toxic volatile organic compound (VOC) emissions by avoiding the painting step. To December 2012, this saved 2,700 gallons of diesel fuel and 60,000 pounds of carbon dioxide by removing 19,200 truck miles to transport the window-trim parts between factories[260].

Reintegration of waste: Interface Carpets worked with its yarn supplier to enable it to send discarded fishing nets from developing nations for reprocessing into nylon yarn. The resulting carpet tiles have improved eco-credentials while providing an income for poor communities from cleaning up their shorelines and reducing damage to marine ecosystems[261].

Risk reduction and confidence to invest: Innocent Drinks, a large user of blueberries, recognised that there are very few growers of blueberries in the UK. It therefore built a longstanding relationship with the leading grower through long term contracts. The grower accepted a lower unit price for produce in return for the surety of the off-take and was able to invest in its business to improve yields and service to Innocent Drinks[262].

Improved social and environmental performance: Certification schemes used by manufacturers, such as the Forest Stewardship Council (FSC) mark, focus on the social and environmental sustainability of raw materials – in the FSC's case, timber. These enable manufacturers to ensure that the materials they use are less likely to harm the ecosystems and communities from which they are sourced. Some companies support projects run by organisations to encourage more sustainable farming practices amongst a large number of supplying farmers (e.g. IKEA and cotton). In 2011, 100,000 cotton farmers were engaged in these projects in India, Pakistan, China and Turkey, resulting in many farmers reducing their use of pesticides by 50%, fertiliser by 30% and water by 50%[263].

Scale purchasing: Pepsico, in India, has developed a relationship with State Bank of India to provide its farmer suppliers with credit at a lower rate of interest[264].

Best practice sharing: Cider maker Bulmers has invested in an orcharding team which provides expertise to all contract apple growers. For example, they provide timely information about growing conditions and pest management each season. This enables

[259] Source: Carbon Trust, Carbon Footprints in the Supply Chain: The next step for business, 2006, p. 12. Analysis done by Booz & Company.
[260] Source: Leach A. 'Ford Halves Window Trim Cost Through Supplier Innovation', Supply Management, 13 Dec 2012, http://www.supplymanagement.com/news/2012/ford-halves-window-trim-cost-through-supplier-innovation/
[261] Source: Shankelman, J., 'Interface Rolls Out the Fishing Net Carpet', Article in Business Green, 8 Jan 2013, http://www.businessgreen.com/bg/news/2234464/interface-rolls-out-the-fishing-net-carpet.
[262] Source: British Broadcasting Commission, 'Peter Jones: How We Made Our Millions', Television documentary, 2001.
[263] https://ic.fsc.org/; IKEA Sustainability Report 2011, p. 30.
[264] Source: http://pepsicoindia.co.in/purpose/environmental-sustainability/partnership-with-farmers.html

farmers to minimise spraying against fungi and insects – reducing costs and environmental impact[265].

Investment benefitting all suppliers: Nestlé India established a dedicated supplier development department in 2005 to achieve cost savings and to create a wider, more flexible supply base. The company invests in technical assistance and training programmes for suppliers related to safety and quality, as well as management systems and products. As a result, Nestle India has diversified its supplier base and saved US$5 million. This initiative has been replicated in Bangladesh, Brazil, Indonesia, Iran, Malaysia, Russia and South Africa[266].

Collaboration amongst suppliers: Clusters of suppliers benefit from working together to create a successful and yet competitive industry-specific ecosystem – such as the diamond cutters in Surat, India and carbon fibre bicycle frame producers in Taiwan. Advantages include industry-specific training, a dynamic qualified labour pool, sub-component suppliers, innovative entrepreneurs, and transport & logistics infrastructure. This enables all participants to improve their quality, productivity and profitability[267].

These benefits can amount to substantial savings. Asda, for example, has identified an estimated £800 million p.a. of savings in their food supply chain, including £60 million of savings available from a pilot group of just 32 suppliers[268]. Given the revenue for Asda in 2012 was £22.8 billion[269] and assuming that approximately 50% of this was spent by Asda on food suppliers[270] (around £11 billion) then the identified estimated saving represents a 7% cost reduction on food purchases.

Further case study examples from the range of manufacturing sub-sectors are presented on the Next Manufacturing Revolution website www.nextmanufacturingrevolution.org in the 'Case Studies' tab.

Resource Productivity Opportunities through Supply Chain Collaboration

Supply chain collaboration enables companies to work together to unlock the energy efficiency, process waste, circular resource flows, transport efficiency and packaging optimisation opportunities discussed in other chapters of this study. The magnitude of these savings and job and environmental footprint benefits have been calculated for the domestic manufacturing sector in the specific chapters (which covered the whole of the UK manufacturing sector and therefore covers manufacturers supplying other manufacturers).

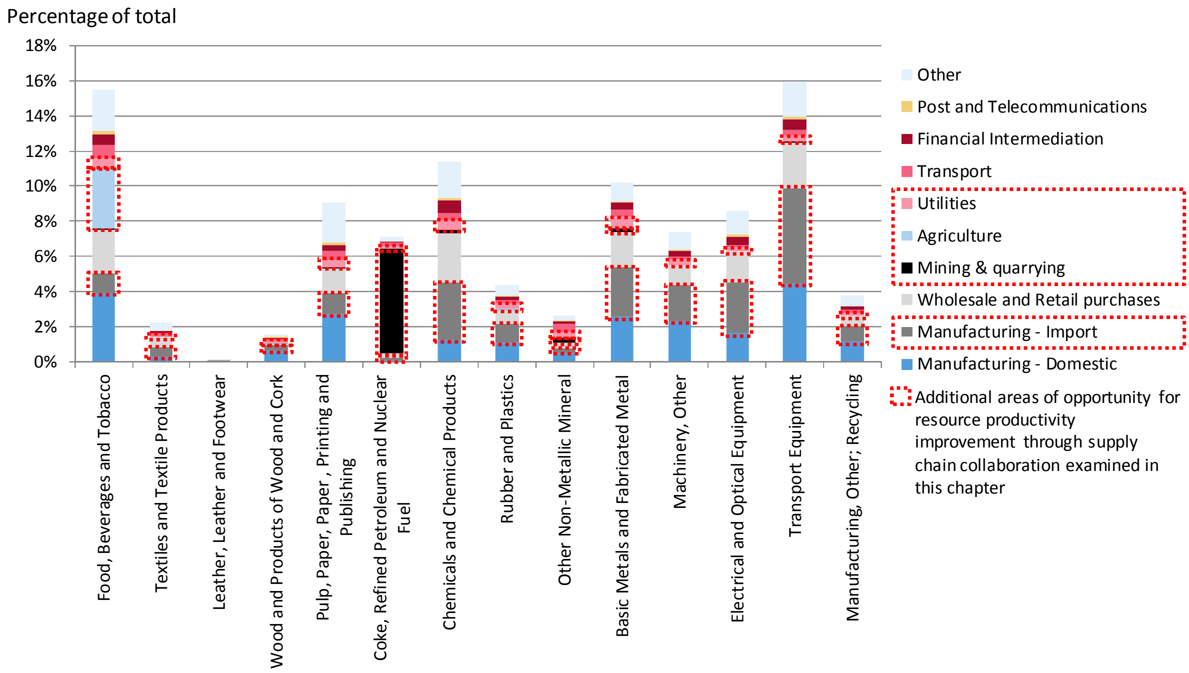
To avoid double counting, this section is therefore focussed on resource productivity improvements in collaboration with suppliers beyond domestic manufacturers; i.e. the **offshore manufacturing**,

[265] Source: "Your monthly round-up of the companies making it happen", Sustainable Business, November/December2011, p. 14.
[266] Source: UN Global Compact Office, Supply Chain Sustainability: A Practical Guide for Continuous Improvement, Jun 2010, pp. 38, 40.
[267] Porter, M. E., Kramer, M. R., 'Creating Shared Value', Harvard Business Review, Jan-Feb 2011.
[268] Sources: 2degrees, Beyond Lean: how sustainability unlocks collaborative efficiencies, 2012, p. 6, at http://www.2degreesnetwork.com/groups/supply-chain/resources/beyond-lean-how-sustainability-unlocks-collaborative-efficiencies/; Private correspondence with 2degrees. 30 May 2013.
[269] Source: http://your.asda.com/archives/press-centre/05/2013 [accessed 29 May 2013]
[270] The 50% figure assumes that 80% of Asda's sales are food, Cost of Goods Sold is 76% of revenue (2013 Walmart global average) and assumes that labour represents 10% of COGS. i.e. 80% x (76%-10%) = 53%

mining & quarrying, **agriculture** and **utilities** sectors – together accounting for **£125bn p.a.** (37%) of UK manufacturers' input costs[271].

Examining inputs according to manufacturing sub-sector (Figure 69) shows that most of the mining and quarrying inputs flow to the coke, refined petroleum and nuclear fuel sub-sector, agricultural inputs mostly flow to the food, beverage and tobacco sub-sector and manufacturing imports and utility inputs are distributed across most sub-sectors.

Figure 69: Breakdown of Total UK Non-Labour Manufacturing Inputs by Sub-Sector, 2009



Note: 'Other' includes renting of equipment, purchasing and maintenance of motor vehicles, hospitality, real estate, and construction.
Source: World Input Output Database, http://www.wiod.org/database/nat_suts.htm

From the sources of value created through supply chain collaboration (shown in Figure 68 above), all either directly improve resource productivity or assist to improve resource productivity (see Appendix 7 which maps the linkages). Working through these, there are a number of obvious resource productivity opportunities in each of the non-labour input focus areas where UK manufacturers can assist their suppliers to make mutually beneficial savings:

1. **Imported manufactured goods**

Other chapters of this report identify substantial resource productivity savings for UK manufacturers in the areas of: energy efficiency, waste reduction, packaging optimisation and transport efficiency. These opportunities also exist for overseas manufacturers, importing goods to the UK.

The UNEP/Wuppertal Institute collaboration, in their report on resource productivity in global value chains, observed that: "the general difference in resource efficiency between developed and developing countries indicates lower resource efficiency in off-shored

[271] Based on 2011 of purchases of goods, materials and services by the UK manufacturing sector, the total of which was £340bn. Source: Office for National Statistics, Annual Business Survey, Section C: Manufacturing, Release date 15 Nov 2012.

manufacturing activities."[272] This suggests that the savings from resource productivity for imported manufactured goods should be at least consistent with those found in the UK manufacturing sector. These savings can be unlocked through UK manufacturers working with their overseas suppliers on best practice sharing and scale purchasing.

Second order opportunities also exist, such as these overseas manufacturers also encouraging their suppliers to improve their energy efficiency. These have not been included in this analysis as they are one step removed from the direct influence of UK manufacturers.

2. Mining and quarrying

Opportunities exist to improve the resource (especially energy) efficiency of mining and quarrying operations, especially in developing nations.

However, commodity prices are generally set on global markets, driven by the supply and demand balance rather than the cost to produce. It is therefore considered unlikely, at least for the medium term, that UK manufacturers would reap any of the financial benefit of resource efficiency measures taken within mines. Therefore no resource productivity savings can be reasonably counted for UK manufacturers from collaborating with their mining and quarrying suppliers.

3. Agriculture

There are significant and widely applicable resource productivity improvements from collaboration with the agricultural sector (whose products are mostly bought by the food, beverage and tobacco manufacturing sub-sector as shown in Figure 69). For example:

a) Reintegration of waste: Use of biological waste from food, beverage and tobacco manufacturing as fertiliser for the agricultural sector. This was discussed in the process waste chapter of this study.
b) Best practice sharing and investment in land productivity benefitting all suppliers: Improving land productivity while reducing energy, water and fertiliser[273] use through sponsoring research and technology development and disseminating the learnings/information to farmers.
c) Best practice sharing, scale purchasing and providing confidence to invest in energy and water[274] efficient equipment: Group purchasing of energy efficient equipment, favourable financing rates and assistance to invest in equipment such as LED lights and efficient pumps.
d) Best practice sharing, scale purchasing and providing contract surety to assist farmers to invest in distributed energy: Assistance with energy generation technologies, including anaerobic digesters, solar photovoltaic systems, solar thermal systems, micro-hydro installations, wind generators and biomass generators. These can lower energy costs and energy price volatility for farmers.

[272] UNEP/Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production, Raising resource productivity in global value chains – spotlights on international perspectives and best practice, 2008, p. 13.
[273] Note that fertilisers are mostly made from fossil fuels.
[274] Note that water requires significant energy to move and treat.

4. Utilities

Utilities are consumed by most manufacturing sub-sectors; resource efficiency opportunities through supply chain collaboration exist in:

a) Demand response (cross-boundary optimisation): Manufacturers can agree to reduce their energy consumption for short peak periods (e.g. by turning off refrigeration units or by turning on their own backup generators for a couple of hours) in return for a fee - saving energy providers from having to make expensive investments in infrastructure (power plants and transmission & distribution assets) to cover occasional peaks in demand.
b) Distributed generation (further cross-boundary optimisation which also reduces supply risks related to price volatility and uncertainty): Manufacturers, often working with utilities, can either use excess heat or waste products to directly generate energy, or install solar PV, biomass or combined heat and power (CHP) units which provide both electricity and heat (which the manufacturer uses on site). CHP units are more efficient than central generation because they utilise the waste heat and, being on-site, avoid transmission and distribution losses which are often of the order of 10%.

The Additional Potential of Supply Chain Collaboration for the UK

Estimating the benefits of supply chain collaboration for resource productivity from imported manufactured goods, mining and quarrying, agriculture and utilities is difficult due to the one-off nature of some opportunities and lack of reliable data for others – as discussed in Appendix 8.

However, there are five areas of opportunity where sufficient information and data exists to allow a conservative estimate of savings to be made. They sum to a potential financial saving of **£390 million p.a.** for the manufacturing sector and a greenhouse gas emission reduction of **1.7 million tCO2e p.a**.

To understand the full potential of supply chain collaboration, these figures need to be added to the potential savings from working with other UK manufacturers in the areas of energy, process waste, transport, packaging and circular resource use (covered in other chapters), which are estimated at £1.41 bln[275]. Combining this with the additional £390 mln p.a. identified here, this suggests a total potential impact from supply chain collaboration of £1.8 bln p.a. – of which only £390 mln p.a. can be added to the total potential of the Next Manufacturing Revolution in the UK to avoid double counting.

[275] UK manufacturers purchase 23% of their £340 bln p.a. worth of goods, materials and services from other UK manufacturers (as per Figure 66) i.e. £78 bln p.a. Given that UK manufacturers' total turnover in 2011 was £512 bln (Source: Office for National Statistics, Annual Business Survey, 15 Nov 2012 release), this means that 15% of this turnover came from selling to another manufacturer. Applying this percentage to the total potential savings from energy, waste, transport, packaging and materials productivity identified in the chapters above (i.e £9.4bln p.a.) suggests that supply chain collaboration could unlock £1.41 bln p.a. of the previously counted potential savings.

The elements of this additional £390 mln p.a. are:

I. Energy efficiency improvements in overseas manufacturers

Conservatively using UK manufacturing energy efficiency savings potential[276] of 0.39% of turnover[277] and applying this to the value of manufactured goods imported by the UK manufacturing sector in 2011 of £75 billion[278] indicates a saving of £296 million p.a. If this is shared such that UK manufacturers receive 50% of the saving, then this is worth **£148mln p.a.** to them.

If greenhouse gas intensities for overseas producers are the same as in the UK[279], this energy efficiency represents a saving of **0.7MtCO_2e p.a.**

II. Transport efficiency improvements in overseas manufacturers

Transport efficiency savings opportunities for the UK domestic manufacturing sector were found in in the transport efficiency chapter of this study to represent 0.17% of turnover. Applying this to imported manufactured goods, and assuming that UK manufacturers receive 50% of the saving, represents a **£65mln p.a.** reduction in costs**.**

At similar greenhouse gas emission intensities for vehicles as the UK[280], this transport efficiency improvement represents a reduction in greenhouse gas emissions of **0.6MtCO_2e p.a.**

III. Improving land productivity

Land productivity good practice examples suggest that manufacturers can assist farmers to reduce their costs in a number of ways, as well as improve their yields by at least 20% to 30%:

- Unilever shares its capabilities with suppliers in areas of expertise including irrigation management. As a result, tomato yields on farms in Brazil have improved by 20% and water usage has decreased by 30%[281].

- PepsiCo India's potato farming program involves over 12,000 farmer families across six states. The program includes providing farmers with superior seeds, timely agricultural inputs and agricultural implements free of charge. In 2010, their

[276] Conservative because UK manufacturing has made substantial energy efficiency improvements since 1990 (refer to the Energy Efficiency chapter of this study) and so the remaining potential for the UK is likely to underestimate the savings available in developing nations.
[277] Refer to the Energy Efficiency chapter of this study, which found a £1.9bn p.a. energy efficiency opportunity based on 2010 figures on a manufacturing sector turnover of £484bn (2010 results from the ONS Annual Business Survey 15 Nov 2012 release).
[278] 22% of £343bn
[279] This is a conservative assumption because many outsourcing nations in the developing world have high emissions intensities for their energy compared to the UK.
[280] This is considered to be a conservative approach given that most outsourcing nations have much lower fuel efficiency standards than the UK.
[281] Source: Brammer, S., Hoejmose, S., Millington, A., Managing Sustainable Global Supply Chains: Framework and Best Practices, Network for Business Sustainability, c. 2010, p. 18.

contract farmers in West Bengal registered a 100% growth in crop output, doubling farm income[282].

- PepsiCo also imported high-yielding varieties of tomatoes to India, increasing yields by over 300% and doubling the length of the tomato season, resulting in a substantial increase of farmer incomes[283].

- British Sugar, working with the National Farmers Union, has increased the yield of sugar beet crops in the UK by 75% since 1980[284]. Since 1982, pesticide application has reduced by 60%, nitrogen by 40% and phosphate application by 70%[285].

- In Idaho, MillerCoors assisted growers to increase their barley yields by 35% since the 1970s[286].

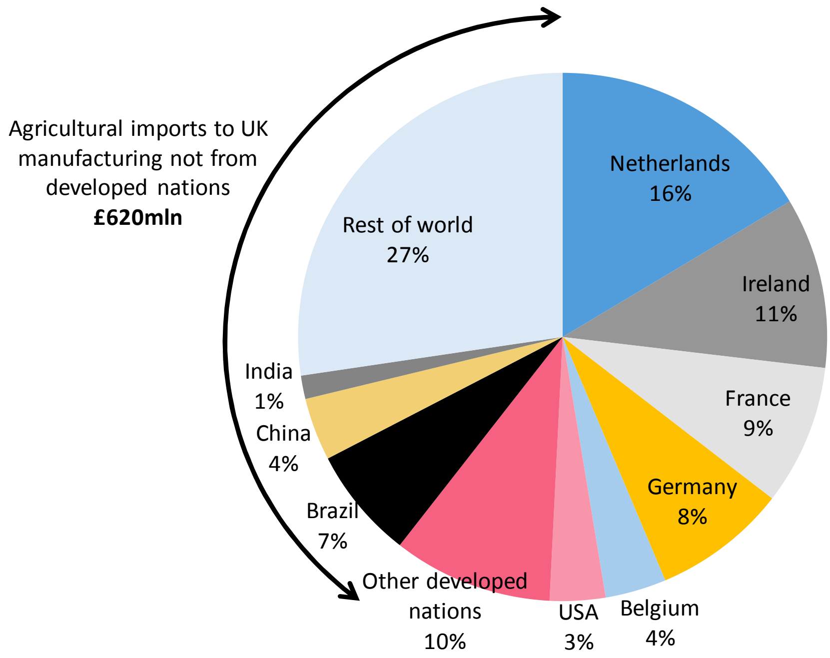
- Cargill, through its Farmer Field Schools, provides tools and training to help farmers improve their business practices, grow better quality cocoa and lift their annual yields by up to 30%[287].

Note that this type of farmer collaboration is not the norm; where it has occurred manufacturers have usually been motivated by the need to improve the security of supply for critical ingredients. That is, significant value (beyond cost savings) accrues to manufacturers through risk reduction.

It is estimated that improving land productivity would create a cost saving for manufacturers of **£62mln p.a.** This assumes a 20% to 30% land productivity improvement translating to a 20% cost saving for farmers, applied only to the £620mln[288] of agricultural produce imported into the UK from developing nations every year for use in manufacturing[289] (see Figure 70) and assuming that manufacturers share 50% of the saving.

[282] Source: PepsiCo website: http://pepsicoindia.co.in/purpose/environmental-sustainability/partnership-with-farmers.html.
[283] Source: PepsiCo website: http://pepsicoindia.co.in/purpose/environmental-sustainability/partnership-with-farmers.html
[284] Source: British Sugar UK and Ireland, Corporate Sustainability Report, 2009/10, p. 15.
[285] Source: UK Beet Sugar Industry, Sustainability Report, p. 4.
[286] Source: MillerCoors website, http://www.millercoors.com/Supply-Chain/Sustainable-Agriculture/Better-Barley.aspx.
[287] Source: Cargill Cocoa and Chocolate, Sustainable Cocoa: Building a Transparent and Sustainable Supply Chain, p. 8, http://www.cargill.com/wcm/groups/public/@ccom/documents/document/na3050295.pdf
[288] Source: World Input Output Database, 2009, http://www.wiod.org/database/nat_suts.htm.
[289] It is assumed that farmers within the UK are assisted by farming and research organisations to improve their productivity.

Figure 70: Imports of Agricultural Products for Use in UK Manufacturing, 2009



Note: 'Rest of world' includes unallocated imports.
Source: World Input Output Database, http://www.wiod.org/database/nat_suts.htm

IV. Assisting the agriculture sector with energy and water efficiency

Assisting the UK agricultural sector to improve its energy and water efficiency could reduce its annual direct energy and water spend of £1bn p.a.[290] by 15%[291] (£150mln). However, because the manufacturing sector only takes 62% of the output of the agricultural sector, only £95mln p.a. relates to manufacturing. If manufacturers share 50% of this, the benefit for the manufacturing sector (specifically the food, beverage and tobacco sub-sector) is **£48mln p.a.**

Greenhouse gas emissions related to the agricultural products going to manufacturing saved through this 15% reduction in energy use is **0.4MtCO_2e p.a.**[292]

V. Collaborating with Utilities on Demand Response

Demand response is saving ISO New England (the independent manager of electricity in the New England region of the US) 9.8% of its peak demand through price-responsive demand, real-time demand response, and real-time emergency generation using existing backup

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[290] 2009 figure of output from energy and water sector used by the agriculture sector from the World Input Output Database, http://www.wiod.org/database/nat_suts.htm.
[291] Source: Warwick HRI, AC0401 Direct energy use in agriculture: opportunities for reducing fossil fuel inputs, University of Warwick, 2007, p. v.
[292] Based on Warwich HRI's findings of a 15% reduction across all direct energy use by agriculture saving 175,000 tonnes of carbon, adjusted to CO_2 by dividing by 27.3% (the proportion of carbon by weight in the CO_2 molecule) and multiplying by 62% - the proportion of agricultural products purchased by the manufacturing sector. Source: Warwick HRI, AC0401 Direct energy use in agriculture: opportunities for reducing fossil fuel inputs, University of Warwick, 2007, p. v.

generators[293]. In return, companies providing the demand reduction (including manufacturers) earn a fee.

The UK, in the form of the National Grid's Short Term Operating Reserve (STOR), currently can reduce its peak demand by 1.4% through load response and back-up generators[294]. ISO New England suggests that an additional 8.4%[295] reduction in peak load through demand response is possible, although the UK's current STOR system would need to be altered (see the Barriers section below).

An 8.4% reduction in the UK's 60GW peak load[296] represents a 5GW reduction. If the manufacturing sector is able to contribute 31% of this reduction (its share of UK electricity use[297]), then manufacturing's potential contribution is 1.56GW of peak load. At an average fee of £45,600 per MW of peak load reduced[298], this is worth **£70 mln p.a.** to the UK manufacturing sector.

Note that demand response does not reduce greenhouse gas emissions because it shifts production timing or relies on the turning on of back-up generators.

Aggregating these five potential additional savings shows substantial financial benefits amounting to over **£390 million p.a.** for the manufacturing sector (see Figure 71). These will impact most manufacturing sub-sectors, with land productivity and agricultural energy efficiency improvements specifically benefitting the food, beverage and tobacco manufacturing sub-sector. Note that this analysis has focussed on benefits to UK manufacturers. The win-win nature of supply chain collaboration initiatives means that suppliers also accrue benefits, as do the community and environment – including through the potential greenhouse gas emission reduction of **1.7 million tCO_2e p.a.** (see Figure 72).

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293 Sources: ISO New England, Demand Resource Asset Enrollments, 1 Mar 2013, p. 2, http://www.iso-ne.com/genrtion_resrcs/dr/stats/enroll_sum/index.html; http://www.iso-ne.com/nwsiss/grid_mkts/demnd_days/

294 Sources: PJM, 2013 Load Response Activity Report, Mar 2013, p. 2, http://www.pjm.com/~/media/markets-ops/dsr/2013-dsr-activity-report-20130314.ashx; p.2, http://www.pjm.com/sitecore%20modules/web/~/media/documents/reports/2012-rtep/2012-rtep-book-5.ashx

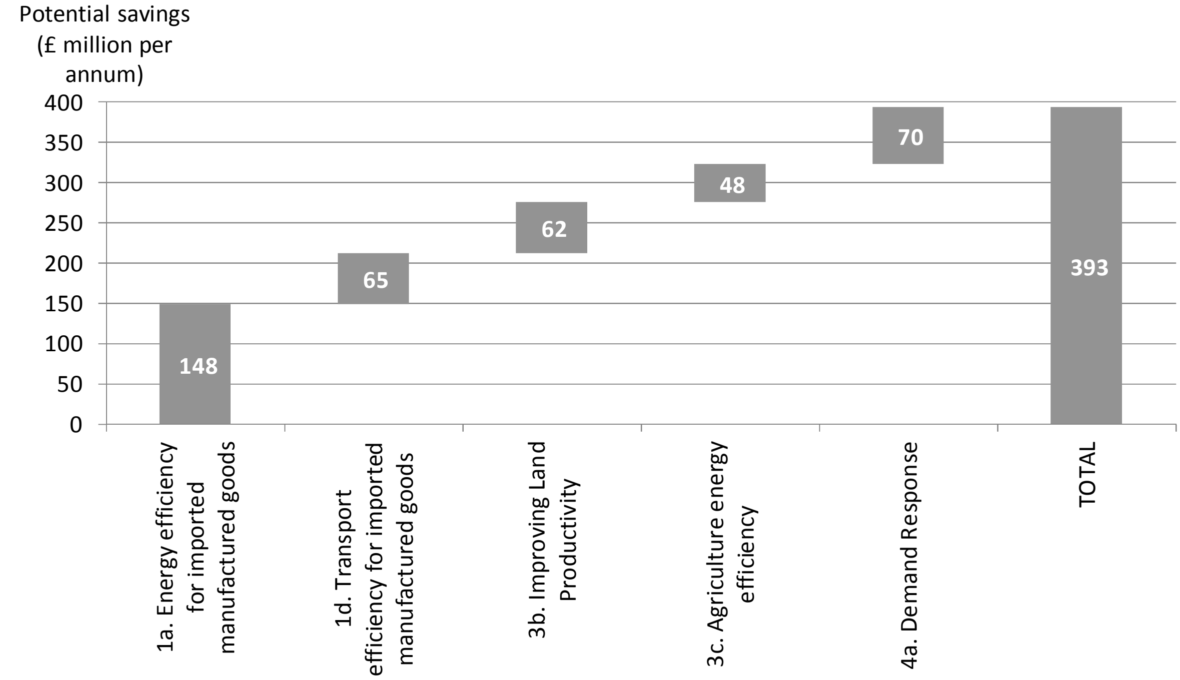
295 9.8% full potential minus the current 1.4%.

296 National Grid website, http://www.nationalgrid.com/uk/Electricity/MajorProjects/EnergyChallenge.htm

297 Sources: Department of Energy and Climate Change, Industrial Energy Consumption, 2010; Department of Energy and Climate Change, Digest of UK Energy Statistics (DUKES), 2012.

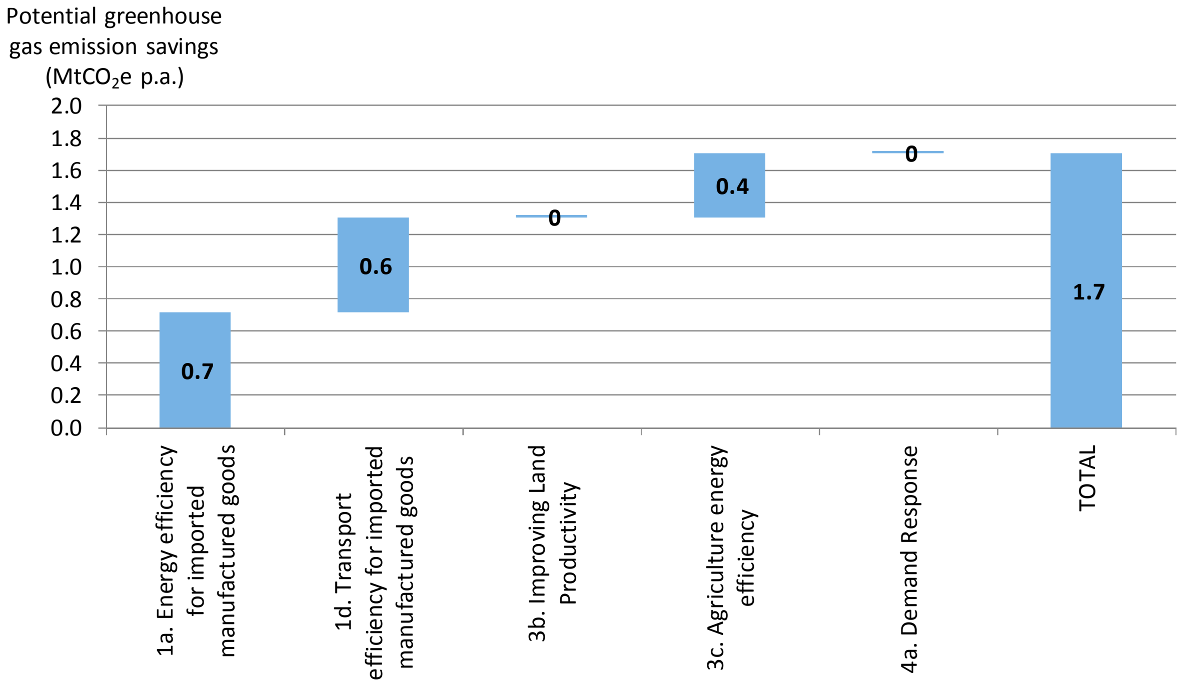
298 Based on Q1 2013 global peak load demand response enrolments of 26,849MW for which US$1.8billion is expected to be paid to providers and assuming an exchange rate of 0.68 GBP/US$. Source: Pike Research report cited in The Energy Collective, 'Industrial Demand Response is Booming, Residential Isn't', 19 March 2013, http://theenergycollective.com/ecsjessica/200311/industrial-demand-response-booming-residential-isnt.

Figure 71: Summary of Potential Additional Manufacturer Savings through Supply Chain Collaboration to Improve Resource Productivity



Source: Next Manufacturing Revolution analysis.

Figure 72: Potential Additional Greenhouse Gas Emission Savings from Manufacturing Supply Chain Collaboration to Improve Resource Productivity



Source: Next Manufacturing Revolution analysis.

The literature supports the view that substantial supply chain collaboration opportunities exist:

- A research team from the Logistics Systems Dynamics Group at Cardiff Business School and Hull University Business School, based on an analysis of 29 companies, found that: "Most of the companies surveyed are still grappling with internal process integration with very few companies achieving closer integration with their customers."[299].

- In their 2011 Global Supply Chain Trends document[300], Geissbauer et al identified five levers to maximise flexibility in the supply chain – which they consider to be the pre-condition for growing company revenues while minimising supply chain costs. All except trend number four recognise the need for greater supply chain collaboration:

    1. Focus on supply assurance and proactive capacity management for critical resources. Close partnerships with key suppliers and fast and appropriate responsiveness are the most important ways to master significant up- or down-swings.
    2. Relentlessly engage in collaborative end-to-end demand and supply planning. Leaders connect, automate, and actively manage real-time information points with all supply chain partners to support rapid and informed decision making.
    3. More tightly integrate with partners' supply chain architectures.
    4. Tear down the wall between supply chain management and product development/ engineering.
    5. Relentlessly drive superior collaboration maturity.

    They found that companies who have implemented the five levers have, on average, reduced supply chain costs by 8% to 10% and achieved a 12% to 15% revenue increase annually. As could be expected given the broad range of benefits from supply chain collaboration[301], these figures are substantially greater than the specific resource productivity-related improvements identified in this chapter which amount to 0.1% of the cost of purchased goods and services by UK manufacturers.

The Next Manufacturing Revolution survey[302] results (see Figure 73) suggest substantial improvement opportunities in supply chain collaboration related to sustainability/resource productivity, consistent with the broader findings of this study. Note that the rates of take-up of the examined initiatives by respondents may be higher than average due to a possible sample bias given the good sustainability track records of survey participants.

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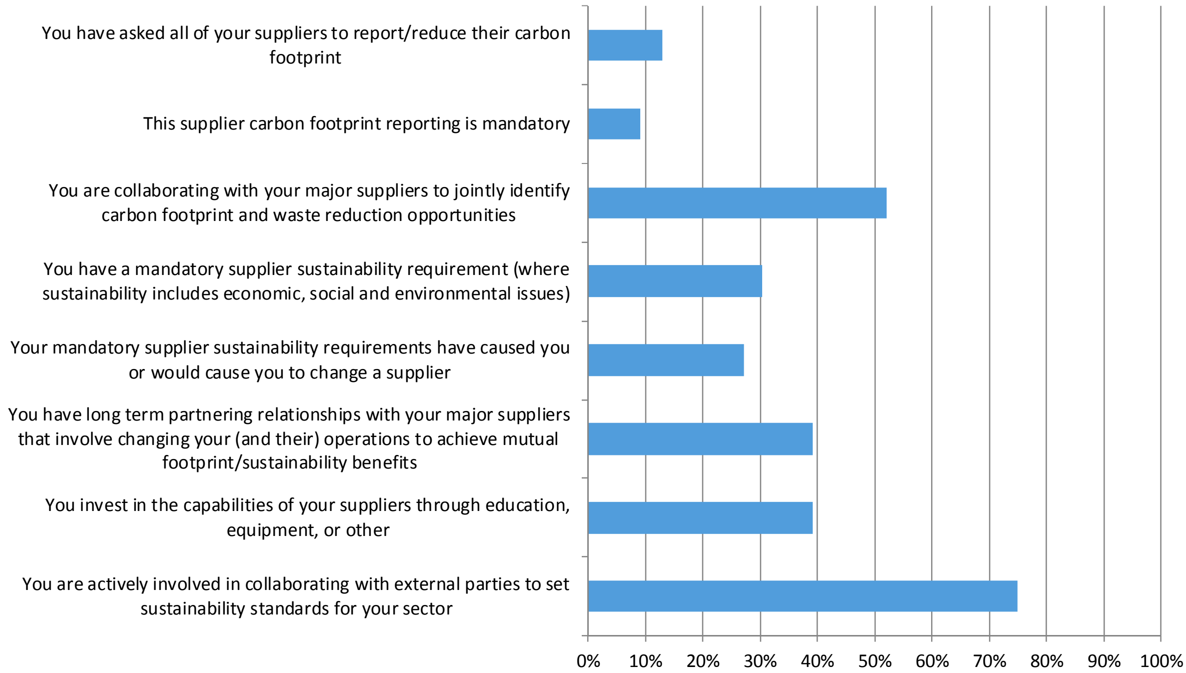
[299] Aryee, G., Naim, M. M., Lalwani, C., "Supply chain integration using a maturity scale", Emerald Group Publishing, Emerald 19, 2008, http://www.emeraldinsight.com/case_studies.htm/case_studies.htm?articleid=1728402&show=pdf

[300] Geissbauer, R., Roussel, J., Takach, J., D'heur, M., Global Supply Chain Trends: flexibility in a volatile world, PwC, 2011.

[301] Including reduced expediting, better crisis management, fewer supply risks, reduced working capital, and more effective planning of inventories and logistics.

[302] For details of the survey see Appendix 3.

Figure 73: Results of Next Manufacturing Revolution Survey Questions Regarding Supply Chain Collaboration: Percentage of Respondents Agreeing with the Statements[303]



Barriers to Supply Chain Collaboration

There are a range of barriers to supply chain collaboration[304]. These are heavily influenced by traditional purchasing practices.

Conventional purchasing practice has evolved to minimise the level of procurement resource (maximising their labour productivity) while minimising the cost per unit purchased. Both of these aims have been achieved by reducing each supplier's offering to a small number of metrics, the most prominent of which is cost per unit. This has the advantage of enabling easy comparison between suppliers and coincides with the profit focus of many companies. While this approach, combined with a number of other practices[305], has reduced supplier margins, it has rarely optimised for value across the whole supply chain.

Further, because the purchasing negotiation has been reduced to a limited number of simple metrics, interactions are adversarial, with one party's win resulting in a loss for the other. This has often contributed to a culture of mistrust between suppliers and customers that makes it difficult to

[303] Note that the survey only gave the response options of 'yes' and 'no'.

[304] Sources include: Interview with the Director of Enterprise Services for 2degrees, which provides supply chain collaboration services to leading retailers in the UK; UNEP/Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production, Raising resource productivity in global value chains – spotlights on international perspectives and best practice, 2008; Bastl, M., Supply chain collaboration framework, Cranfield School of Management, c. 2012, http://www.projectscale.eu/wp-content/uploads/2013/01/Marko_Bastl.pdf; Benavides, L., De Eskinazis, V., Swan, D., 'Six steps to successful supply chain collaboration', Supply Chain Quarterly, Quarter 2 2012; Slone, R.E., Dittmann, J.P., Mentzer, J.T., The New Supply Chain Agenda : The 5 Steps That Drive Real Value, Harvard Business School Publishing Corporation, 2010; Next Manufacturing Revolution survey.

[305] Practices vary by sub-sector and include own-branded items and sourcing from low labour countries.

access shared value opportunities. For example, a customer approaching a supplier to reduce their energy use could be treated with suspicion; the supplier may be concerned that the customer, on identifying the opportunities, may wish to capture all of the value available, leaving the supplier to carry out the efficiency activities for no reward. There is therefore a potential dis-incentive for suppliers to share information on their activities and a lack of transparency and trust makes collaboration difficult. This is exacerbated in situations where a power asymmetry exists (i.e. one party is significantly larger than the other).

While mechanisms such as supplier checklists and product certification have emerged in the last decade to address a number of issues not covered by the limited number of purchasing metrics, most of these only examine downside risks[306] rather than tapping into shared value opportunities.

Within this context, barriers to supply chain collaboration fall into six key categories which are interdependent:

1. **Senior Executive Leadership**. Only senior executives within both suppliers and customers can lead the culture change necessary to build better trust and commit the resources and data necessary to collaboratively engage with their suppliers/customers; middle managers are not able to challenge cultural norms and/or existing business practices. Within customers specifically, senior executive commitment is needed to provide the resources necessary to hold a deeper conversation with what can be thousands of suppliers; traditional purchasing teams do not have the time or skills to actively engage in multi-organisational value optimisation.

2. **Information**. To commit to collaboration, senior executives must be aware of the size of opportunities. Competitive rivalry and adversarial supplier-customer relationships means that little information on collaborative opportunities is available; good practices are hidden, along with how to achieve them. In other cases, supply chain collaboration opportunities, such as Demand Response, are new and unknown. Lacking knowledge of the opportunities available, and with an adversarial history, customers are poorly equipped to approach suppliers with improvement requests related to resource productivity (or any other collaboration-based improvement) – resulting in limited progress.

3. **Resources**. Most suppliers have developed processes and invested in equipment to meet customer needs. Changes to this current asset base before the end of its economic life add cost for suppliers. For example, requirements to pack in-field mean that farmers need to purchase new equipment and write off large packing sheds that their customers had previously required them to invest in. To drive the investment required to unlock supply chain opportunities, customers must share the benefits or otherwise compensate suppliers (e.g. with longer supply contracts).

   Customers must also invest in resources to address the trust and logistical difficulties of having frequent and deep conversations with a large number of suppliers. While modern IT platforms are emerging to overcome this hurdle, these also require investment to establish and run.

[306] Examples of checklist items are avoidance of child labour and human rights abuse (e.g. Nike), environmental certification (e.g. timber certification), and product quality and authentication checking (compare the recent horse meat substitution).

4. **Skills**. The Energy Efficiency chapter of this study outlined the capabilities required to unlock energy efficiency opportunities, which also apply to most of the specific supply chain collaboration opportunities identified above:
    a. Engineering/technical know-how to identify technical solutions for ancillary as well as core production activities, fit them into business circumstances and de-risk them.
    b. Commercial skills to develop robust investment cases to secure funding in tight economic conditions and to identify new business models.
    c. Change management skills to educate staff, motivate new behaviours, stimulate action in many instances beyond business-as-usual activities, secure support for projects and work with multiple parties.
    d. A systems perspective to look beyond single-unit/company improvements to find cross-system optimisation opportunities.

    Supply chain collaboration requires additional skills of:
    e. Facilitation to overcome the adversarial history between companies, building trust over a long enough time to overcome doubts through careful and consistent relationship management.
    f. Communication to reinforce the commitment of senior executives to multiple layers of management in a range of departments and across what can be thousands of suppliers.
    g. Data management to capture, manage and analyse a wide range of data across a large number of suppliers over time.

    Given the tensions between suppliers and customers, intermediaries are being used to both provide the skills necessary and act as impartial referees ensuring that commitments are upheld and that all parties are treated fairly. For example, 2degrees has assisted Tesco and ASDA to successfully drive their supplier collaboration programs. A second example, TRI-VIZOR, a spin-off from the University of Antwerp, is orchestrating horizontal supply chain collaboration (between suppliers) in Northern Europe[307].

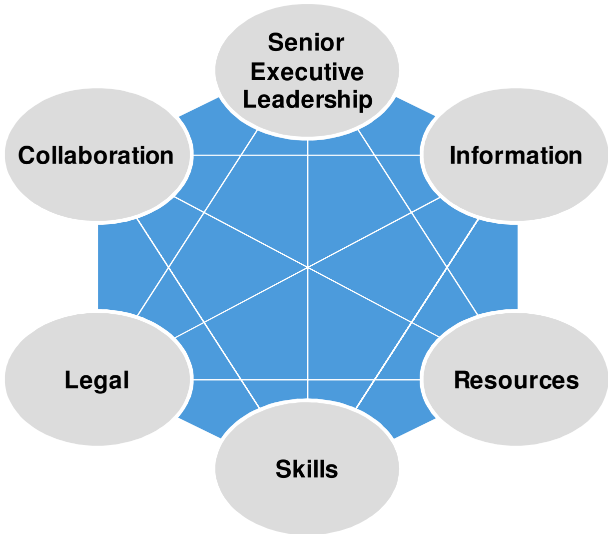
5. **Legal Constraints**. The only type of demand response possible in the UK is through the Short Term Operating Reserve (STOR), administered by the National Grid. This is a market for balancing services, a type of demand response that only a minority of industrial customers are flexible enough to participate in[308]. Specifically, National Grid's rules state that STOR providers must be able to[309]:
    - Offer a minimum of 3MW or more of generation or steady demand reduction (this can be from more than one site);
    - Deliver full MW within 240 minutes or less from receiving instructions from National Grid;
    - Provide full MW for at least 2 hours when instructed;
    - Have a Recovery Period after provision of Reserve of not more than 1200 minutes (20 hours);
    - Be able to provide STOR at least 3 times a week.

[307] See 'JSP and HF-Czechforge to bundle plastics and steel shipments from Czech Republic to Germany', CO^3 Project, 5 Dec 2011, http://www.co3-project.eu/wo3/wp-content/uploads/2011/12/JSP-Hammerwerk-CO3-Case-study.pdf.
[308] Source: Personal communication with Phil Martin, Principal, Market Development at Enernoc, 11 Mar 2013.
[309] Source: http://www.nationalgrid.com/uk/Electricity/Balancing/services/balanceserv/reserve_serv/stor/.

Creating new rules to enable demand response to be easily bid into the dispatch merit order would assist manufacturers to benefit from this new solution to cost-effectively addressing peak demand.

6. **Collaboration**. Clearly supply chain collaboration requires suppliers and manufacturers to work together, sharing information and details of their operations. For this to occur, suppliers need to be confident that they will receive a fair share of the value created. This trust can be difficult for some suppliers if they are smaller than the manufacturer or have historically been treated poorly by them.

Figure 74: Supply Chain Collaboration Barriers



Chapter 9: Revenue Growth from Non-Labour Resource Productivity

Chapter Summary

Previous chapters of this study have focused on cost reduction associated with resource productivity - revenue upside potential also exists. Revenue growth occurs (through price uplift or increased volume) when a manufacturer creates value for customers. This can occur through non-labour resource productivity at various stages in a product's life cycle, including:

- Product manufacture (making more resource efficient products that have higher customer preference)
- Product deployment (efficient delivery models such as Product Service Systems/'servicising')
- Improving product in-use efficiency (by reducing either cost/impact per usage, or overall usage and hence increasing customer preference and saving operating costs)
- Re-use of products (including through new business models such as collaborative consumption)
- Remanufacturing (as discussed in the Circular Resource Use chapter)

All sub-sectors can benefit from improved efficiencies in product manufacture, whereas some are not suitable for additional value capture in the other areas listed above because their products are used in further manufacturing steps in other sub-sectors (e.g. primary metals, basic chemicals).

Innovation is occurring both in product design/formulation and in new business models (such as 'servicising'). New business models can take market share rapidly, transforming markets to the benefit of innovators and detriment of laggards.

Chemical and machinery companies who have developed more resource efficient offerings are showing a revenue uplift/premium of 1% to 2% p.a. Adopting resource efficient offerings across the various chemical and engineering/machinery sub-sectors would generate to additional profits worth **£325mln p.a.** for these sub-sectors alone.

There are four key barriers to revenue growth from non-labour resource productivity, namely senior executive leadership to drive what is often substantial change, information availability (case studies, incentive alignment, cost transparency and clear standards), resources (for product development, business model design and testing, and marketing) and a suitable skill set.

Context for Revenue Growth Discussion

Four chapters of this report[310] concentrate on opportunities within the boundaries of an individual organisation's activities. The previous chapter on supply chain collaboration identified optimisation opportunities for organisations to work together along their value chains, with a focus on upstream participants in the value chain. This chapter is focused on opportunities to capture additional value from resource productivity by working with customers and consumers within the value chain.

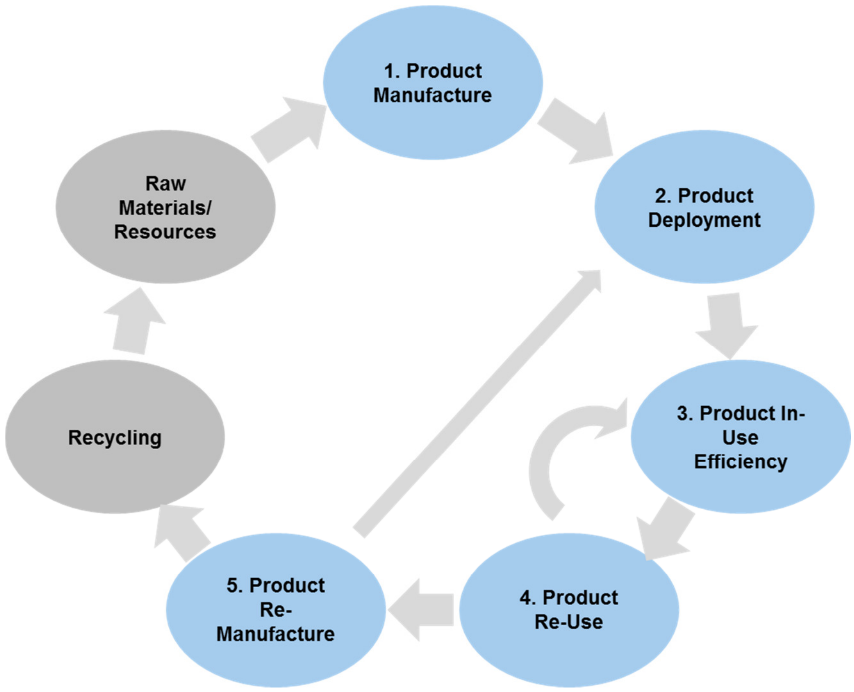
Whereas previous chapters have looked at cost reduction, this section examines revenue upside from non-labour resource productivity.

[310] Energy efficiency, process waste, packaging optimisation and transport efficiency.

Introducing Revenue Growth from Non-Labour Resource Productivity

Additional revenue occurs where manufacturers create value for customers. This customer value translates into company revenue through either higher prices or increased volume (as the company's products are chosen ahead of competitors' at the same price point). The greater the customer value, the greater the revenue that should result. It is therefore instructive to identify where and how non-labour resource productivity creates customer value; this is done below by examining each stage of a product's life (Figure 75):

Figure 75: Product Life Cycle



Source: Lavery Pennell

1. In **product manufacture**, substantial resources can be saved, as discussed in previous chapters. For example, by improving the energy efficiency of a manufacturing process or by using different materials (e.g. bioplastics), a company's products may have a lower embodied resource usage. This gives improved resource productivity within existing business models. For example:
    - P&G track their development of 'Sustainable Innovation Products': products that have a >10% improvement compared to previous or alternative versions of a product in one or more of energy use, waste production, transportation, material used in packaging or products, or substitution of non-renewable energy or materials with renewable sources. To date, P&G state that they have achieved $52bn in cumulative sales of such products[311].
    - Henkel's Factor 3 program seeks to triple the value Henkel creates for its footprint, by 2020. As part of this the company is developing products that deliver better performance while saving resources and lowering environmental impacts. This builds on previous programs where all new products had to contribute to sustainable development in at least one area (of energy

[311] Source: P&G 2012 Sustainability Report, p7.

consumption, water consumption, waste generation, health & safety and social progress)[312].

While the manufacturer can reduce its costs significantly, the product user and community also benefit from reduced environmental impacts. Many manufacturers expand such programs to reduce/eliminate potentially harmful substances ranging from toxins to sugar (in the case of nutritional benefits).

These actions can create value for manufacturers beyond pure cost savings in the form of improved brand equity, customer loyalty and customer preference over alternative products.

Key levers: Energy efficiency, process waste reduction, circular resource use, packaging reduction, transport efficiency, supply chain collaboration

2. **Product deployment**. Manufacturers can improve how some products are deployed, resulting in significant resource productivity increases. This is often referred to as creation of a Product Service System or 'servicising' i.e. providing a service rather than a product to a customer. Value is created because:
    - Products are designed and/or specified to most efficiently perform the desired user requirements
    - Manufacturers understand the servicing and maintenance requirements of their products
    - The optimal conditions for the longevity and performance of products can be created through monitoring and information sharing
    - Incentives are aligned for the manufacturer to design products and maintenance regimes that maximise their first life and performance
    - It enables manufacturers to keep control over products, increasing their value in the reuse/remanufacturing stage

    Examples include:
    - Rolls-Royce 'Total Care', which charges customers on a $ per engine flying hour basis. This fee covers services such as predictive maintenance as well as repair and overhaul activities. It delivers higher reliability and 'time on wing' thus improving resource productivity per engine while adding value for customers through avoided breakdowns and delays[313].
    - Many paint companies have moved from supplying paint to automotive Original Equipment Manufacturers (OEMs) to providing automotive finished coatings. Because the paint manufacturers are paid per vehicle, they have developed new application systems (such as heat cured powder coatings) which reduce overall paint use, increase line speed through reduced drying time, and reduce HSE risks from paint spray[314].
    - Fuji Xerox and Ricoh (and others) have moved from provision of photocopiers to 'photocopied pages'. Through predictive maintenance and use of closed loops for photocopier machinery, resource utilisation has been improved[315].

[312] Source: Henkel Sustainability Reports 2012 & 2009.
[313] See http://www.rolls-royce.com/civil/services/totalcare/ for further details.
[314] See 'Sustainability through Servicizing', Rothenberg, MIT Sloan Management Review, Winter 2007.
[315] See the Circular Resource Use chapter, for a fuller explanation.

- Philips offers 'pay per lux' where they specify, install and replace lightbulbs in return for a regular fee based on the light hitting work surfaces where it is needed[316].

The value created through greater asset and information sharing is spread between the customer and manufacturer. The customer can pay a lower overall price, while the manufacturer can achieve a higher price per unit of product because there is much greater efficiency/less wastage.

Key levers: Correct specification, optimised maintenance, design for purpose, improved control over and knowledge of products' condition to better re-use and remanufacture them.

3. **Product In-Use Efficiency**. By creating products and services that help customers/consumers to use fewer resources (either by reducing impact per use or amount of usage), resource productivity within the in-use phase can be improved[317]. For example:
    - P&G have observed that the vast majority of energy used in the clothing value chain is in the home, for heating water used in washing machines. Cold wash detergents therefore provide an overall value chain improvement in energy usage, saving their customers money on their energy bills[318].
    - BASF offer a range of 'Climate Protection Products' which generate less GHG emissions along the entire lifecycle (production to disposal) than relevant alternatives. Examples include insulation for buildings, motor vehicle fuel additives, and nitrification inhibitors[319].
    - Vitsoe design and manufacture furniture which is intended to 'be as useful for as long as possible' (along with designs which never become obsolete), improving in-use efficiency by extending product lifetime.

    The value from product in-use efficiency mostly benefits the customer (with environmental benefits for the entire community). However, the manufacturer benefits from improved brand equity, customer loyalty and customer preference over alternative products, leading to higher market share.

    Key levers: Design for in-use efficiency

4. **Re-use**. At the end of a product's first use, re-using a product with minimal adjustment can save substantial resources compared with customers buying new products[320]. A range of re-use models exist which incorporate different offerings:

[316] See http://turntoo.com/projecten/rau/
[317] Assuming that the reduction in customer/consumer resource usage does not require a correspondingly larger increase in resource usage within the manufacturer.
[318] See http://www.pg.com/en_UK/sustainability/environmental-sustainability/products-and-packaging.shtml for more details (other FMCG companies offer similar products), also 'Why Sustainability is Now the Key Driver of Innovation', Nidumolu, Prahalad and Rangaswami, Harvard Business Review, September 2009, p57
[319] See http://www.basf.com/group/corporate/en/sustainability/environment/climate-protection/co2-bilanz-2012 and BASF Corporate Carbon Footprint 2012: Assessment of Emissions Avoided Through Use of BASF Climate Protection Products, for further details. In 2012, BASF reports emissions from operations of 25 million tonnes CO_2e, whilst they claim customers avoided 320 million tonnes CO_2e through use of these products.
[320] For some products (e.g. cars, white goods), in-use efficiency may evolve quickly enough over time that new models can use less resources through the product life, sufficient to offset the higher up-front cost of a new product.

- **Second hand sales** have existed for a long time, for many durable products. In such a sale, the customer who owns the product shares the saved value with the buyer. Whole ecosystems have developed and evolved to reduce the cost of matching sellers with buyers. AutoTrader magazine and eBay are examples; they secure a fee for their matching services.
- **Rental/Leasing of Products:** Rental companies, for example, typically save users capital expense, maintenance and storage costs in return for a rental/leasing fee.
- **Collaborative consumption** has emerged recently[321], facilitated by modern IT and social media, as well as demand for products for shorter usage periods and the desire to avoid up-front capital and storage costs. For some products, such as cars provided through sharing schemes such as Zipcar, insurance, fuel, breakdown assistance and local siting have added value to the customer proposition. Other products, such as household equipment are shared through simple low-cost matching sites such as NeighborGoods and StreetBank.

The value from re-use flows mostly to the customer/asset owner and buyer/ user, with some being taken by the facilitating company. It would appear that manufacturers have not yet fully embraced the customer lock-in, guaranteed product offtake and brand benefits from owning collaborative consumption facilitation companies.

Key levers: Matching of buyers with sellers (or temporary users with product owners), bundling of complementary services, convenience, increased utilisation

5. **Remanufacturing**. This subject is covered in depth in the Circular Resource Use chapter of this study, which discusses the cost savings to manufacturers. Remanufactured products also sell in many instances below the price of new products (a 20% discount was assumed in the Circular Resource Use opportunity sizing calculations). This discount will enable UK manufacturers to take market share from overseas competitors selling new products. With market share comes increased scale which can further reduce costs (e.g. by increasing purchasing power and spreading fixed costs over a larger volume).

   Value therefore flows to customers through lower prices, to manufacturers through increased revenues and scale, and to the community through environmental and social benefits (including jobs).

   Key levers: Developing a virtuous cycle for remanufacturing[322].

In summary, resource productivity can provide manufacturers with a range of benefits throughout the first five stages of the product life cycle that increase revenue as well as reduce unit costs through lower resource use and scale benefits. The revenue benefits include:

- Brand equity (justifying higher prices or leading to greater volume)
- Customer loyalty (justifying higher prices or leading to greater volume)
- Higher prices per unit of product
- Guaranteed product offtake (increasing volume)

[321] See http://www.wrap.org.uk/content/innovative-business-models-1 for numerous examples.
[322] Refer to the Circular Resource Use chapter.

Applicability of Revenue Growth through Resource Productivity to Specific Manufacturing Sub-Sectors

The value able to be generated at each stage of the product lifecycle by specific manufacturing sub-sectors is presented in Figure 76. Sub-sector applicability is based on a number of logical premises:

- There are fewer options for product deployment in sub-sectors that are far removed upstream in the value chain (e.g. primary metals processing and oil refining)
- Product deployment, re-use and remanufacturing are not applicable for sub-sectors where the product is not retrievable (e.g. food & beverage)
- Opportunities for in-use efficiency work best around discrete assets (most notably vehicles or equipment), rather than molecules from process industries, as it is easier to define how much usage each party has obtained

Figure 76: Applicability of Growth Opportunities to Manufacturing Sub-Sectors

Sub-Sector	1. Product Manufacturing	2. Product Deployment	3. Product In-Use Efficiency	4. Re-Use	5. Re-manufacturing
Food, beverage and tobacco	✓				
Textiles, wearing apparel and leather products	✓	✓		✓	✓
Wood, paper products and printing	✓		✓	✓	✓
Coke and refined petroleum products	✓				
Chemicals and chemical products	✓	✓	✓		✓
Basic pharmaceutical products and preparations	✓				
Rubber, plastic and other non-metallic mineral products	✓	✓	✓		✓
Basic metals and metal products	✓			✓	
Electrical, electronic and optical products	✓	✓	✓	✓	✓
Machinery and equipment n. e. c.	✓	✓	✓	✓	✓
Transport equipment	✓	✓	✓	✓	✓
Other manufacturing and repair	✓	✓		✓	✓

All sub-sectors allow for efficiencies in product manufacturing. Additional value-capture around product deployment, in-use efficiency, re-use and remanufacturing is most prevalent for sectors with engineered products and to a certain extent chemical and similar products. Basic metals and refined petroleum products are less relevant here as they are further removed up most industry value chains and their products become embedded/used in further manufacturing steps in other sub-sectors.

Company/Good Practice Revenue Growth from Non-Labour Resource Productivity

Value capture opportunities in Product Manufacture can be achieved within existing industry value chains. This has been the focus of many manufacturing companies, as it does not require changes to existing business models or customer value propositions. However, as presented in previous chapters of this study, even here most manufacturers are achieving only small annual improvements relative to the potential available. Some, but not all, in-use efficiencies can also be achieved within existing industry value chains.

Revenue benefits without changing business model (i.e. where manufacturers improve resource productivity during Manufacture or In-use) appear to accrue more from additional sales volume than from price increases. Various market research studies have identified a UK consumer willingness to pay a price premium for 'green' products[323]. However, this price premium has often failed to materialise in reality[324], leading a number of commentators to suggest that a premium should not be relied upon[325]. However, evidence suggests that a small premium may be achievable for a limited proportion of customers; one Lavery Pennell client, for example, achieved a 3 to 4% premium for a resource efficient product representing 15 to 20% of their sales volume in one market[326].

Capturing resource productivity value at other life cycle steps (i.e. Product Deployment, Product Re-Use, and Product Re-Manufacture) usually requires new business models[327], which can be disruptive to implement. However, these business models can create substantial competitive advantage for the adopter, leading to up-take by close competitors[328]. New models and revenue growth in the product deployment stage of the life cycle are most usually associated with Product Service Systems (PSS), or 'servicising'. PSS is most applicable to sectors where a service is relatively easy to define, hence the examples to date focusing on hours of machine running (for engineered equipment), or price per copy (for photocopiers) or price per painted vehicle (for paint companies). There are many challenges associated with shifting from a product to a service offering, most notably how to define the revenue model and how to share value between supplier and customer. Once these initial hurdles are overcome and a PSS model is well defined, the market can shift very quickly. Figure 77 shows the rate of this shift for PSS models in the chemicals and aero engine sectors.

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[323] See, for example "Green Appetites", RSA, 2009 (47% of consumers willing to pay a 3.8% price premium on average) and "Our Green World", TNS, 2008 (55% of consumers willing to pay a 5% price premium; 33% willing to pay a 10% premium)

[324] See 'Strategies for the Green Economy', Makower (2009), Chapter 6, for a good overview of this phenomenon.

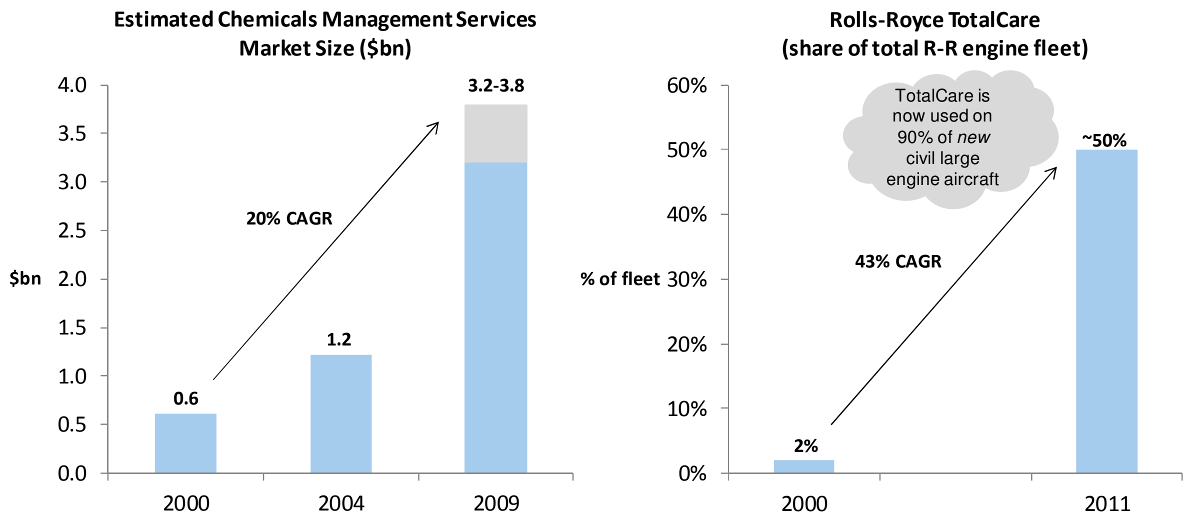
[325] See 'Green to Gold', Esty & Winston (2006), Chapter 5.

[326] Source: Lavery Pennell project with a global market-leading manufacturer.

[327] The following sources present some of the emerging new business models: 'Raising Resource Productivity in Global Value Chains', CSCP (2008) and http://www.wrap.org.uk/content/innovative-business-model-map for examples of different business models; Nidumolu, Prahalad & Rangaswami 'Why Sustainability is Now the Key Driver of Innovation', Harvard Business Review, September 2009 for a discussion on the link between sustainable products/business models and growth; 'Sustaina 100 – A Guide to 100 Sustainable Solutions', Sustaina (2013).

[328] Unlocking the value discussed above (including through the adoption of a new business model) can be copied rapidly by similar companies. If this were to occur for all manufacturers, then any competitive advantage would erode, returning all manufacturers to previous levels of profitability. However, most markets in the UK are extensively served by manufacturers from around the world, many of whom may struggle to follow the new product changes or business models. For example, it is difficult for an Asia-based low-cost manufacturer to offer a servicised solution. Therefore, there is potential for all UK manufacturers in a sub-sector to change their products or business models and benefit by taking market share from overseas manufacturers.

Figure 77: Rate of Introduction of 'Servicised'/PSS Models[329]



Sources: Chemicals Strategies Partnership, Chemicals Management Services Industry Reports 2000, 2004, 2009; www.flightglobal/directory/rolls-royce; Houses of Parliament, PostNote number 420, September 2012, 'Advanced Manufacturing'.

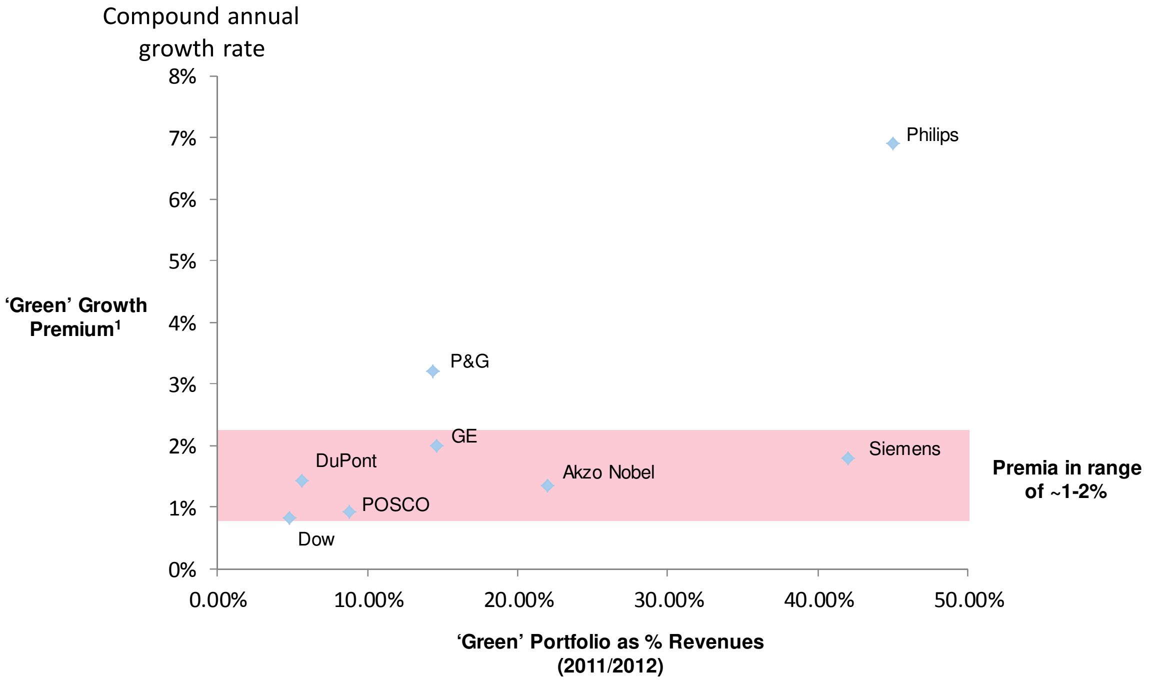
Chemicals Management Services (CMS) are still a small proportion of the overall global chemicals market, but have been growing at a rate of 20% p.a. It has been a particularly successful model in key sub-segments, most notably the provision of painting services to automotive manufacturers. Similarly Rolls-Royce's TotalCare offering for its aero engines has grown from 2% of the total Rolls-Royce engine fleet to around 50% of their total engine fleet in 11 years, a growth rate of 43% p.a. (and is now used on 90% of new large engines used for civil purposes).

For new business models, revenue growth can more easily be derived from price increases because, as discussed above, the total cost to a customer can be reduced while increasing the profit per unit to the manufacturer through greater efficiency/reduced wastage.

Whether or not revenue growth comes from price increase or volume growth, a range of major companies in the chemicals and machinery sub-sectors report an increasing proportion of their revenues coming from 'greener' products. Figure 78 shows the growth premium (average company revenue growth over and above the average growth achieved by the non-'green' portfolio) that companies have achieved over several years.

[329] Source: Chemicals Strategies Partnership, Chemicals Management Services Industry Reports 2000, 2004, 2009; www.flightglobal/directory/rolls-royce; Houses of Parliament PostNote 420, September 2012, 'Advanced Manufacturing'.

Figure 78: Examples of Revenue Growth from more Resource Efficient Products[330]



Note: (1) defined as average annual revenue growth rate for entire product portfolio – average annual revenue growth rate for non-'green' portfolio
Source: Company websites, Annual Reports and Sustainability Reports

It appears that more resource efficient offerings are driving higher revenue growth rates for companies of between 1% and 2%. This premium seems to be consistent regardless of the proportion of 'green' products within a manufacturer's portfolio[331].

Value for the UK from Revenue Growth through Non-Labour Resource Productivity

Revenue upside opportunities are most obvious for the various engineering/machinery sub-sectors, along with the chemical-related sub-sectors. In 2011, these sectors had revenues of £194.6bn[332].

As we have seen, companies with a focus on developing more resource efficient offerings show a revenue uplift/premium of 1% to 2% p.a. Applying a 1.5% revenue uplift to the relevant UK manufacturing sectors[333] suggests a £2.9bn p.a. revenue premium.

At average profit margins across the sectors of interest, this equates to a **£325mln p.a. profit uplift**[334] for UK manufacturing as a whole.

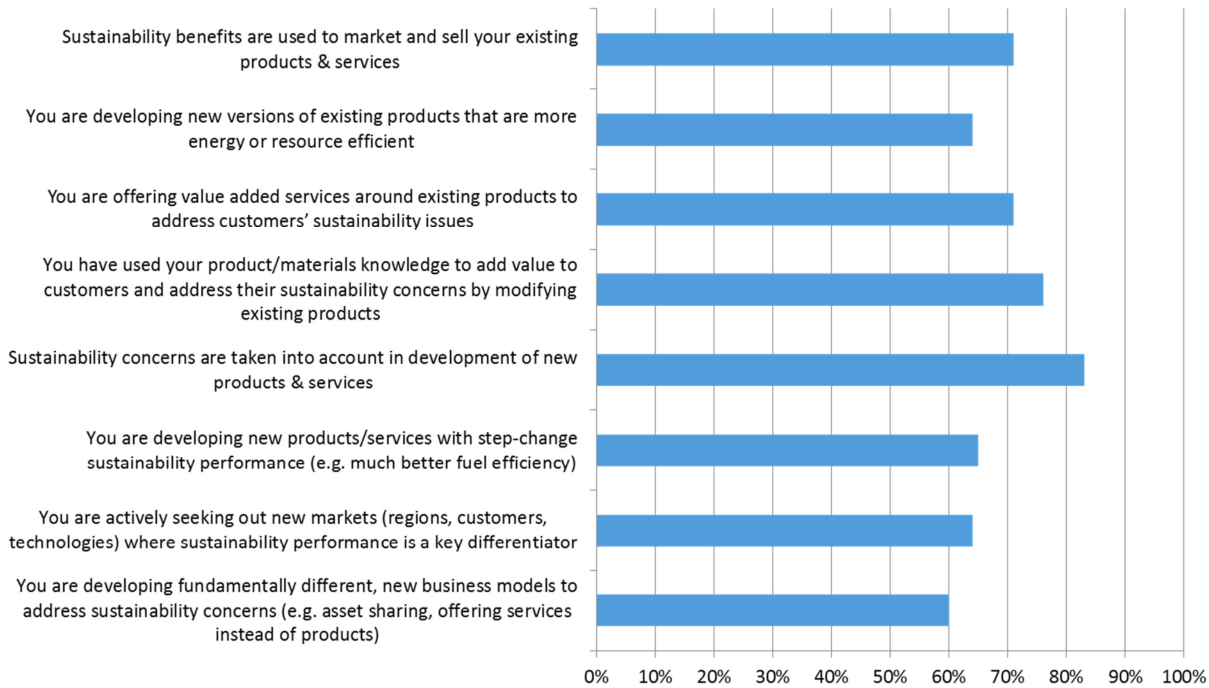
[330] Sources include company Sustainability Reports, Annual Reports and company websites.
[331] It is recognised that there are challenges to using this information, including (a) Being able to disentangle a real focus on resource efficiency on the part of the company from products that already existed, and; (b) Definitional issues: companies report this information in many different ways (e.g. % of products that were better than previous generations; % of products that reduce customer GHG emissions). However, given the scarcity of quantitative data on this subject, this represents an initial step towards building a factbase.
[332] ONS, Annual Business Survey, Section C-Manufacturing, November 2012
[333] Chemicals (Division 20), Rubber & Plastics (21), Electrical equipment (27), General purpose machinery (28), Motor vehicles (29) and Transport equipment (30).
[334] Using ONS, Annual Business Survey, Section C-Manufacturing, November 2012 data, which shows a profit before tax of 11% for the relevant sub-sectors.

This is a conservative approach, for several reasons:

- No relative market share gains were assumed for implementation of new business models such as servicising or collaborative consumption
- The 1-2% uplift identified earlier is conservative as many of the companies have focused their efforts to date on internal resource efficiency and in-use efficiency, rather than driving adoption of new business models

The Next Manufacturing Revolution survey results (see Figure 79) show that the majority of surveyed companies are already thinking about or engaged in growth-related opportunities, especially related to existing products and services (consistent with the conservative approach above). Note that the rates of take-up of the examined initiatives by respondents may be higher than average due to a possible sample bias given the good sustainability track records of survey participants.

Figure 79: Results of Next Manufacturing Revolution Survey Questions Regarding Growth Opportunities: Percentage of Respondents Agreeing with the Statements[335]



Barriers to Revenue Growth from Non-Labour Resource Productivity

The four key barriers (shown in Figure 80) to achieving the full potential from revenue growth associated with more resource productive products and new business models are:

1. **Senior Executive Leadership**. Case studies suggest that where a successful shift to a new business model has happened (e.g. IBM, Xerox[336]), corporate leadership defined the need to change to a service-based model. Given the challenges, especially around alignment of incentives, coupled with cultural shifts and the necessary change management, achieving

[335] Note that the survey only gave the response options of 'yes' and 'no'.
[336] See 'Servicizing: The Quiet Transition to EPR', Tellus Institute, May 1999.

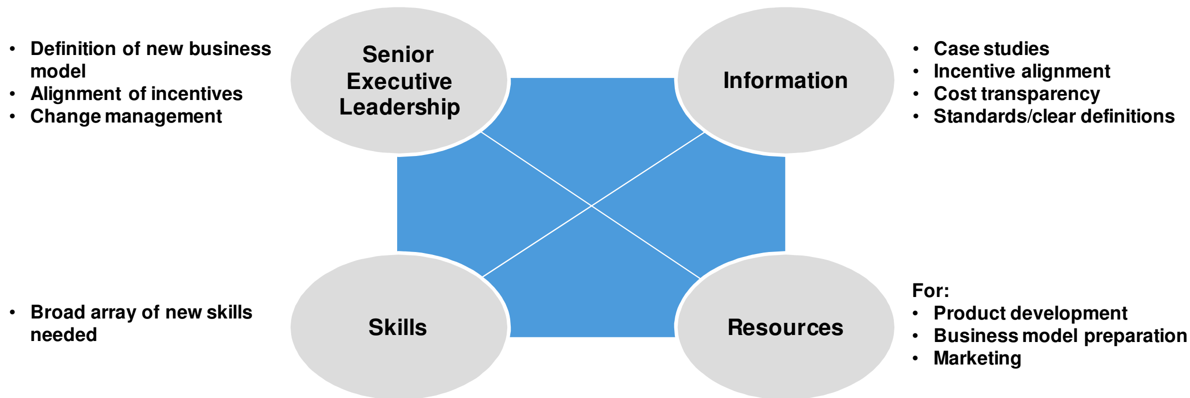
the identified opportunities requires engagement of senior executives throughout the process of putting a new business model in place.

2. **Information**.There are several dimensions to the information barrier related to revenue growth:
    a) Several of the potential **business models are relatively new** (e.g. servicising and collaborative consumption). Successful case studies and credible market information which would promote growth of such business models are in their early days, but building over time.
    b) Several of these new business models require close alignment of incentives between supplier and customer to maximise value from the opportunity, and **hence detailed information sharing along a value chain**. This requires trust between participants and senior executive leadership to make it happen.
    c) Building the business case for new business models such as PSS requires making **true costs transparent** (e.g. for Chemicals Management Systems, true costs go well beyond purchased cost and include transportation, internal handling, testing etc.). This requires aggregation of non-traditional information sources.
    d) Even for some of the opportunities relating to efficiency in-use, there is **no single standard approach to calculating lifecycle impacts** – these can then be confusing and complex to communicate to customers and consumers.

3. **Resources.** Capturing additional revenue either through additional sales or price increases requires customers to be aware of the additional value that resource productivity creates for them – this usually requires marketing expenditure and salesperson time. Product development involves design and research costs. New business models require research, development and testing prior to implementation. These all require investment of resources.

4. **Skills.** To capture substantial revenue growth, companies need to acquire a deeper understanding of customer businesses to be able to deliver servicised business models, requiring a range of skills, some of which will need to be brought into the company. These skills can include strategy, product development, legal/contract development, negotiation, pricing, process redesign, logistics, marketing, change management and commercial skills to build the business case.

Figure 80: Revenue Growth from Non-Labour Resource Productivity Barrier Ecosystem

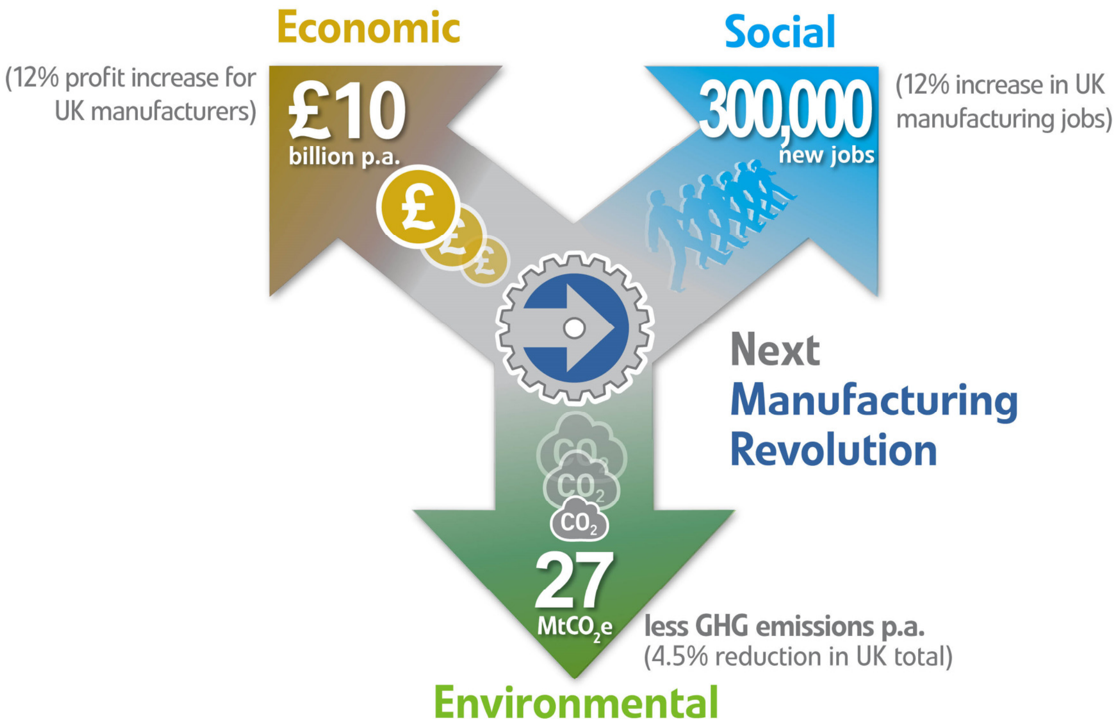


Chapter 10: Conclusion - A Substantial Opportunity for UK Manufacturers and UK plc

Combining the benefits calculated for each of the seven opportunity areas covered in the preceding chapters, the conservative view of the potential for non-labour resource productivity in the UK is:

- **£10 billion p.a.** in additional profits for manufacturers. When averaged over the entire sector for 2011, this represents a 12% increase in annual profits[337, 338].
- **314,000 new manufacturing jobs** (a 12% increase in manufacturing employment based on 2011 figures[339]).
- **27 million tonnes of CO_2 equivalent p.a.** less greenhouse gas emissions from manufacturing-related activities (4.5% of the UK's total 590MtCO_2e greenhouse gas emissions in 2010[340]).

Figure 81: Tri-Benefit Diagram Showing the Economic, Social and Environmental Benefits of the Next Manufacturing Revolution



Note that these figures have been calculated in the chapters above to avoid double counting; ascribing total savings figures to specific topics is difficult because some aspects overlap. For example, supply chain collaboration can cover most of the topics; waste can include process waste and circular resource use.

337 Office for National Statistics, Annual Business Survey – Section C Manufacturing, Release date 15 Nov 2012.
338 Note that some manufacturers may choose to pass on some or all of their cost reductions to customers – enabling them to increase sales, take market share from overseas-based competitors (for most sub-sectors), and benefit from increased scale of production. Note that for most sub-sectors the transformation of all UK manufacturers to a lower cost base does not erode the competitive benefits of resource productivity because of the substantial proportion of imported products in the UK market.
339 Office for National Statistics, Annual Business Survey – Section C Manufacturing, Release date 15 Nov 2012.
340 DECC, 2011 UK Greenhouse Gas Emissions, Provisional Figures and 2010 UK Greenhouse Gas Emissions, Final Figures By Fuel Type And End-User, Statistical release, 29 Mar 2012, Table 7.

It is recognised that there will be some second order impacts as savings in one area affect others. For example, reducing packaging can reduce transport costs. However, these impacts are considered to be small and within the range of accuracy of the savings estimates.

Payback Periods and the Revolving Fund Approach

Overall average payback periods for resource productivity opportunities have been observed to be less than three years:

- The Australian Energy Efficiency Obligation program demonstrated an average payback period for implemented energy efficiency initiatives of **2.4 years**[341].
- The Carbon Trust, in their 2010 paper[342], noted that, based on their experience, a large organisation can save 15% of their energy at an average internal rate of return of 48% (i.e. a payback period of **slightly over two years**) through actions which are Incremental, Process/Systemic and Structural.
- Envirowise found that a payback period of **less than a year** could usually be achieved on waste reduction projects[343].

These rates are consistent with the successes of pioneering companies who have mostly complied with the typical company payback hurdle rate for projects of three years[344].

However, amongst the array of opportunities presented under each topic, some require less investment and hence pay back more rapidly than others. Incremental initiatives typically require minimal investment and pay back very quickly (well under a year). Process and Systems changes can require modest investment, but often pay back within the year. Structural projects can require several years to pay back. Core Redesign initiatives can also have longer project development and payback periods.

This spectrum of payback periods has meant that companies have been able to begin with fast payback opportunities and use the savings that they generate to fund more expensive/longer payback projects (typically Structural Change and Core Redesign). This 'revolving fund' approach has the benefit of avoiding competition for scarce investment capital while also generating momentum for the ongoing program with early successes.

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[341] Australian Department of Resources, Energy and Tourism (DRET), Energy Efficiency Opportunities Program Continuing Opportunities 2011: Results of EEO Assessments reported by participating corporations, DRET, 2012, p. 15

[342] Carbon Trust Advisory Services, The Business of Energy Efficiency, Carbon Trust, c. 2010. http://www.carbontrust.com/media/135418/cta001-business-of-energy-efficiency.pdf.

[343] Insight East, Towards greater resource efficiency in the East of England: A strategic framework and current activity in resource efficiency and waste market development in the context of the emerging regional economic strategy, Version 2 October 2004, p. 5.

[344] Source: Lavery Pennell experience.

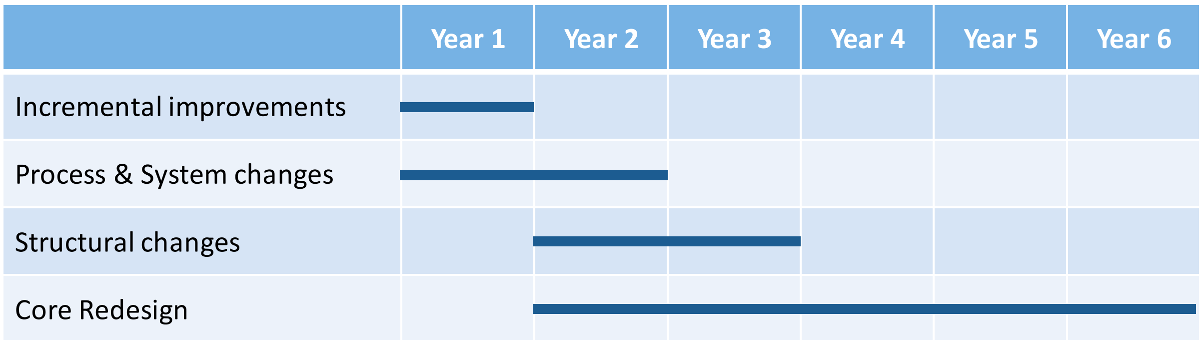
Timing of Types of Project

The nature of the types of actions to improve resource productivity and the benefits of adopting a revolving fund approach mean that the benefits calculated in this study do not all occur immediately:

- Incremental improvements can be implemented quickly and achieve their full potential by the end of one year.
- Processes and Systems changes, which can be designed and commenced quickly, can take time to be accepted and become standard practice; our experience is that implementation takes two years.
- Given the higher capital cost of Structural improvements, many good practice companies delay Structural projects until savings from Incremental and Process & Systems changes can help to fund them. Delaying for one year would mean that planning for Structural changes could begin in year two and likely take two years to design, gain approval and implement.
- Core Redesign is slower because it is often done at major strategic review points for manufacturers (e.g. when considering a new distribution strategy). Core Redesign projects can take five years or more, with planning beginning as early as year two consistent with the revolving fund approach.

Figure 82 illustrates this phasing, presenting a view of a rapid but realistic/achievable implementation of resource productivity within a manufacturer[345].

Figure 82: Indicative Rapid Implementation Phasing of Resource Productivity Initiative Types



Source: Lavery Pennell Experience

Further Benefits for Business and the Community

The benefits above have been calculated conservatively and represent only the direct benefits for the manufacturing sector. Additional financial benefits are expected to include:

- Additional manufacturing revenues and profits from improved **international competitiveness**.
- Savings for **other sectors through supply chain collaboration** (with whom the savings are assumed to be shared). For example, from manufacturers assisting the UK agricultural sector to improve its energy and water efficiency, the UK agricultural sector has the potential to save £48mln p.a.[346].
- **End-user savings** in energy and water bills from using more resource efficient products.

[345] Source: Lavery Pennell experience.
[346] Based on the calculations in the Supply Chain Collaboration chapter.

For the UK government and society, improved non-labour resource productivity leads to:

- Improved **employment** (within manufacturing and indirectly in support sectors) with consequent reduction in social security payments and increased national insurance contributions and personal tax income[347].
- Additional manufacturing jobs from improved **international competitiveness** leading to the relocation of manufacturing back to the UK for some sub-sectors.
- Expertise, new products, **jobs and export earnings** in the emerging fields of non-labour resource productivity (e.g. development of energy efficient equipment) as UK consultants and manufacturers sell their offerings domestically and export them overseas.
- Improved **balance of payments** from resource productivity requiring less energy and material imports. For example, circular resource use is expected to save £30 billion[348] of goods, services and materials – much of which will be raw materials imported from overseas.
- Increased corporate **tax revenues**.
- Reduced expenditure on **energy and transport infrastructure**.
- Improved national energy and resource **security** (including food, energy and raw materials)
- Reduced environmental **pollution** from manufacturing (including helping to meet the country's **greenhouse gas emissions** commitments)
- Reduced direct and indirect **community impact** from manufacturing and support activities ranging from fewer waste disposal sites to reduced traffic congestion.

Areas of Greatest Opportunity Depend on the Company

The evidence of this study suggests that non-labour resource productivity improvement opportunities exist for every company, but that the areas of opportunity will differ between companies:

Significant variance in performance between companies in the same sub-sector was observed amongst the blue chip companies researched – as can be expected with differing business strategies, differing levels of adoption of aspects of non-labour resource efficiency, varying levels of awareness of potential improvement opportunities and varying extent of senior executive commitment to improvements.

Even pioneering companies such as Toyota Europe, Interface and Unilever revealed inconsistent performance across the topics studied and the four types of improvement activities identified (i.e. Incremental, Processes & Systems, Structural change and Core Redesign).

Many companies are not aware of the opportunities now available (including new technologies and business models), as seen by the incremental levels of improvement over the last decade (e.g. packaging intensity improvement of 0.9% p.a.; energy intensity improvement of 1.5% p.a.; flat transport spend) with the exception of waste which has seen substantial improvements.

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[347] It is recognised that minor job losses can accompany changes such as those involved in improving non-labour resource productivity. However, it is expected that these losses will be smaller than the new jobs created.

[348] Calculated as £85bln 2010 spend on goods, services and materials for the Electrical, electronic and optical products, Transport equipment (excluding private cars), and Other machinery and equipment sub-sectors x 50% remanufacturing rate x 70% reduction = £30bln. For details of the rates assumed refer to the Circular Resource Use chapter.

Chapter 11: A Programme of Action to Drive Resource Productivity

Eight recurring barriers were identified across the seven non-labour resource productivity topics examined. The first three of these are relevant for most topics, with the importance of the latter five varying depending on the opportunity:

1. Senior executive leadership
2. Information
3. Resources
4. Skills
5. Design
6. Legal
7. Infrastructure
8. Collaboration

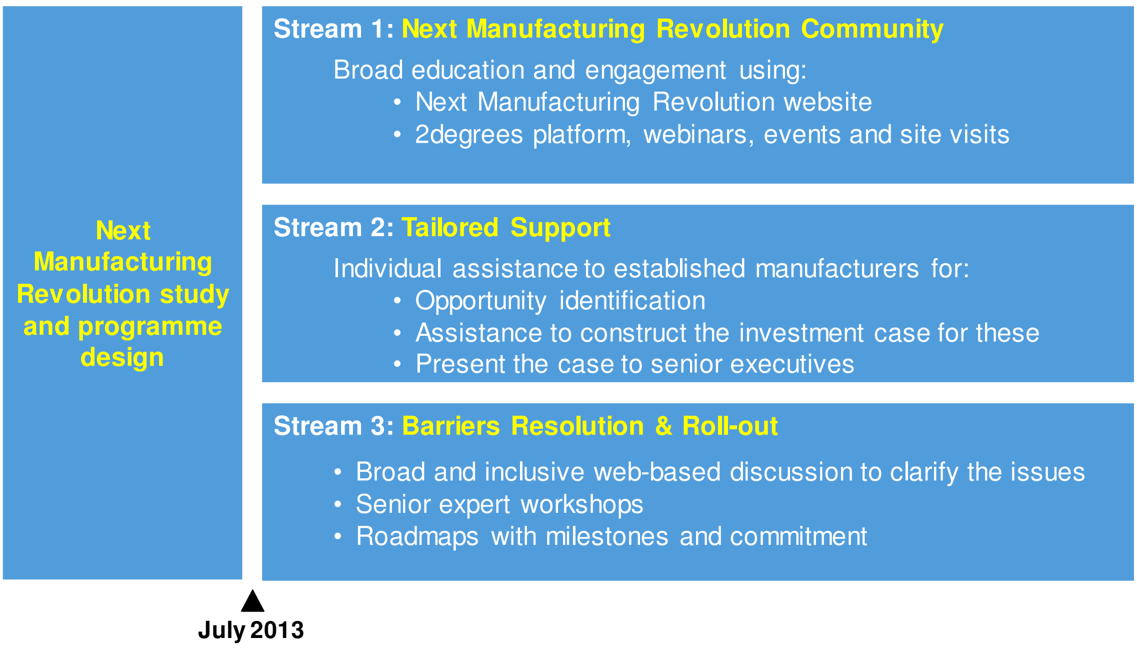
This study represents just a first step in the Next Manufacturing Revolution – beginning to address senior executives and provide information, raise awareness and justify the investment of resources in (and presenting a framework for) building the business case for change.

A programme of action has been developed to address the barriers. It comprises three streams:

1. Broad engagement and education through the creation of an NMR Community
2. Tailored support for individual organisations
3. Barriers resolution and roll-out through workshops and roadmapping

These are discussed in detail below and presented graphically in Figure 83.

Figure 83: Programme of Action to Drive Non-Labour Resource Productivity in the UK



Next Manufacturing Revolution Community

Many of the Next Manufacturing Revolution topics have been embraced enthusiastically by manufacturing staff around the country. However, feedback from peer reviewers revealed the need for more detailed and practical information on how to transform a company's resource productivity. Sub-sector specific case studies, expertise sharing, benchmarks and tools are needed to address the information gaps and start to develop the necessary skills to drive change.

The Next Manufacturing Revolution website and 2degrees platform (serving over 31,000 members) will assemble, house and act as the primary dissemination points for this vital information.

An outreach program, potentially including webinars, conferences and site visits will be led by 2degrees. This will provide information and tools, enable interactive information exchange forums and peer-to-peer discussions, develop skills amongst manufacturing staff and inspire senior executive leadership.

Membership-based organisations and publications are now sought to assist with this engagement and education. Interested groups can contact secretariat@nextmanufacturingrevolution.org.

Tailored Support

Given that the opportunities for resource productivity improvement will vary in each company, the need for a tailored approach is recognised. This tailoring will be most effective where savings will be significant (i.e. for established manufacturers).

The aim of this support, to be provided by the Next Manufacturing Revolution's founding members and led by Lavery Pennell, is to find the biggest opportunities available and provide advice on business case development – addressing the information barrier, augmenting internal skills, and assisting to develop compelling business cases[349] for senior executive approval.

Established manufacturers wishing to be involved can contact secretariat@nextmanufacturingrevolution.org.

Barriers Resolution and Rollout

While the above streams begin to address the key barriers, more concerted action is also required, working with the different stakeholders who can together overcome them.

The barriers presented in this document, which have been reviewed by over 40 peer reviewers, are a starting point for a broader discussion amongst the manufacturing community (to be facilitated by 2degrees) which will culminate in expert workshops, ideally held by manufacturing sub-sector, to design solutions. These workshops will involve senior representatives from manufacturers, relevant government departments, leading NGOs and subject matter experts.

[349] These business cases should including all costs and benefits/value available to a company from resource productivity and be presented in the language of business. That is, including risks, capex, payback periods, IRR, NPV, cash flow, brand value enhancement, commodity volatility reduction, sustainable competitive advantage, and supply security.

Once solutions to barriers are identified, roadmapping discussions will create a timeline for action and secure commitment.

The first workshop is planned for October 2013 and will be led by the University of Cambridge's Institute for Manufacturing. It will focus on the automotive sub-sector.

This collaborative approach will provide a more thorough understanding of the issues to all participants, based on a range of perspectives and provide a variety of potential solutions. We believe that this approach will create both good solutions and ensure support for these – accelerating action on resource productivity far more effectively than a list of ideas assembled in a report.

Representative bodies are sought to convene barriers and roadmapping workshops around the Next Manufacturing Revolution for their sub-sectors. Interested organisations can contact secretariat@nextmanufacturingrevolution.org.

The Role of Government

Government can assist to address the barriers to improving resource productivity.

An enabling and responsive approach by government is perhaps best suited to the nature of the barriers: Enabling because resource productivity already has a strong economic value proposition for manufacturers, and; Responsive because of the large number of inter-related barriers identified, with more likely to be discovered as companies continue to innovate.

Recent history also shows that aggressive regulatory measures can result in immediate and vocal opposition, partly as a reaction to change and also from increasing awareness that opposition leads to concessions. Further, the uncertainty that occurs when dramatic interventions are announced, developed and revised creates risk for companies, impeding their ability to optimise businesses and invest long term in equipment and infrastructure. The European Emissions Trading Scheme is a tangible example where industry concessions diluted the effectiveness of the scheme. Such an adversarial situation would hinder the speedy development of solutions to barriers.

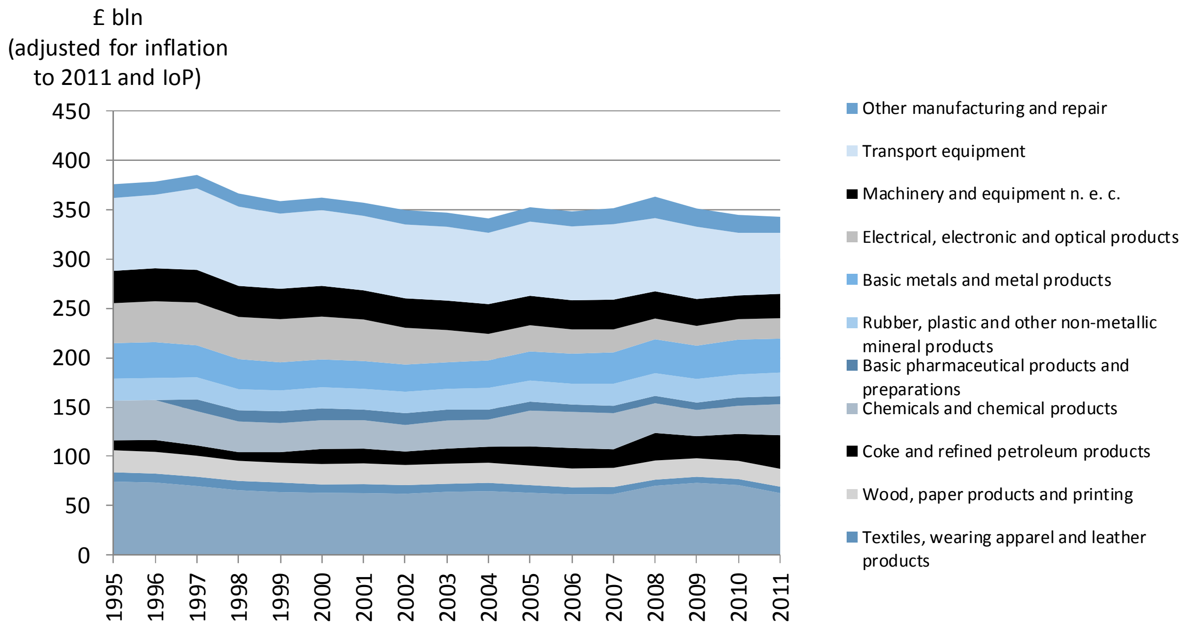
Participation in the barriers workshops and roadmapping by appropriate government departments is therefore both welcome and vital – to ensure that the appropriate level of assistance is provided based on a detailed understanding of how companies approach resource productivity and the challenges that they face.

To date, relevant UK government departments have been supportive of the Next Manufacturing Revolution and we welcome ongoing collaboration.

Appendix 1: UK Manufacturing Sub-Sector Non-Labour Input Intensity Trends

Purchases of goods, materials and services by the UK manufacturing sector, adjusted for inflation and production output, have been decreasing at an average of 0.6% per annum for the last 16 years, although have been flat in in recent years (see Figure 84). This indicates that the UK manufacturing sector as a whole has achieved limited improvements in non-labour resource cost reduction, to date.

Figure 84: Historical Purchases of Goods, Materials and Services by UK Manufacturing Sub-Sector, Adjusted for Inflation to £2011 and Adjusted for Production Volumes[350]

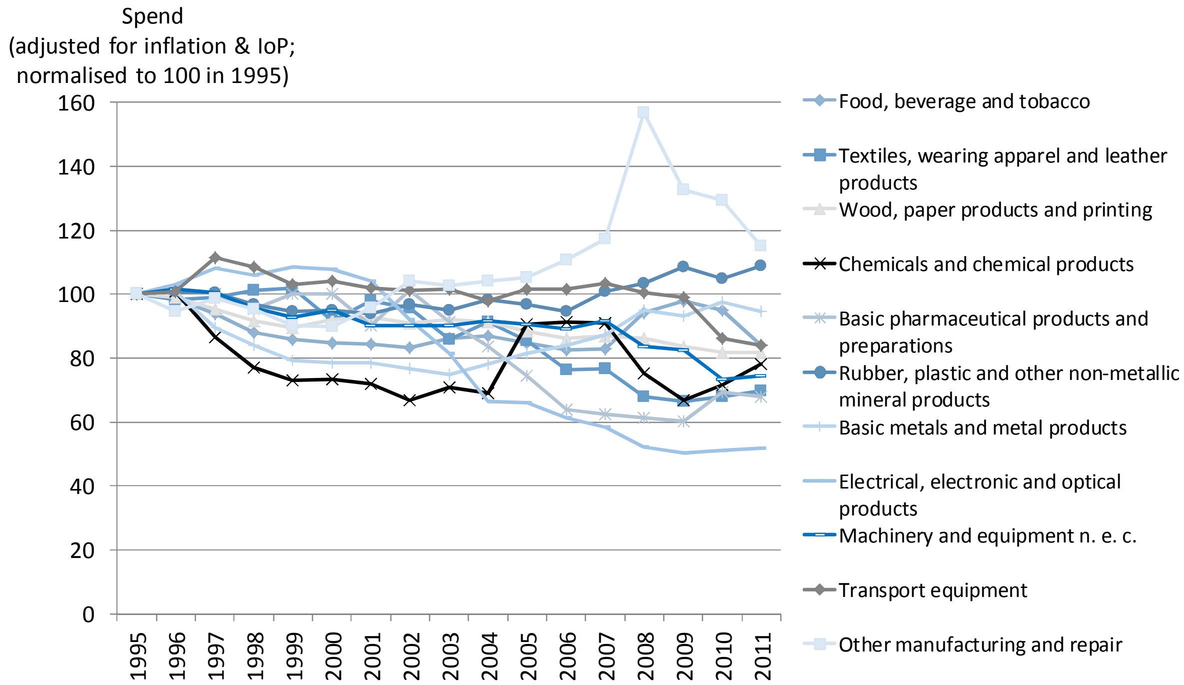


Sources: Office for National Statistics, Annual Business Inquiry, Section C Manufacturing, Release date 14 Jun 2012; Office for National Statistics, Detailed Indices of Production, 2011; World Bank website for CPI for the UK.

Figure 85 normalises all sub-segment non-labour spend to 100 in 1995 and shows that only the textile and electrical, electronic & optical products sub-sectors reduced their unit input spend by more than 30% since 1995 – an annual compound improvement of 2.35% or more. Progress in electrical, electronics & optical manufacturing has been assisted by rapid technology evolution – a development particular to that sub-sector.

[350] By dividing by the Index of Production for each year for each sub-segment, indexed to 1 in 2011.

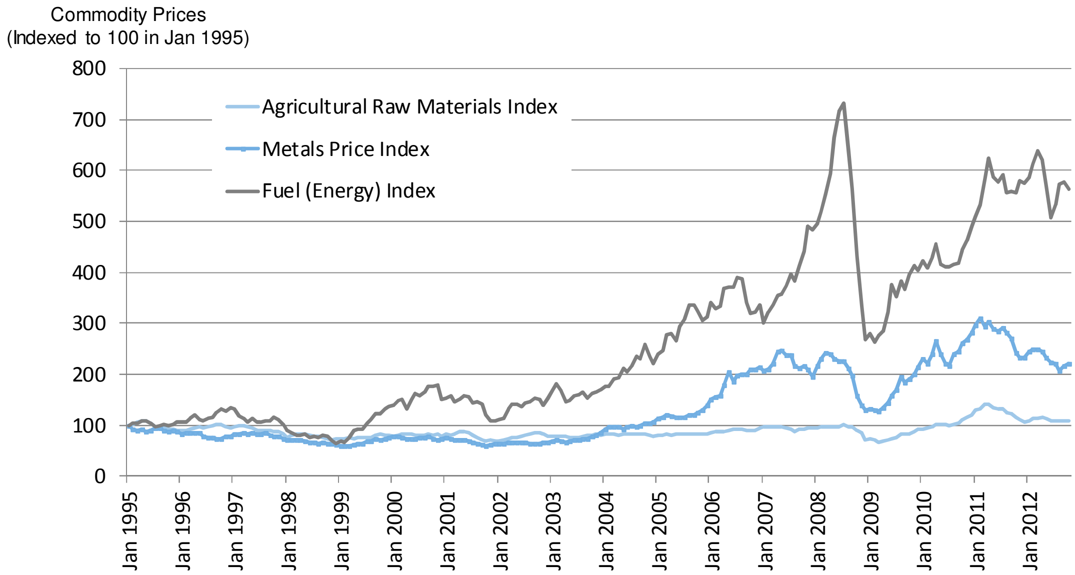
Figure 85: Spend on Goods, Materials and Services by Manufacturing Sub-Sector Adjusted for Inflation and Production Volumes, Indexed to 100 in 1995



Sources: Office for National Statistics, Annual Business Inquiry, Section C Manufacturing, Release date 14 Jun 2012; Office for National Statistics, Detailed Indices of Production, 2011; World Bank website for CPI for the UK.

Sub-sectors relying on agricultural products (food, beverage and tobacco, wood and paper, rubber) have largely kept their input costs flat since 1995, consistent with flat agricultural commodity prices (see Figure 86).

Figure 86: Commodity Price Indices over Time



Note: Agricultural raw materials index includes Timber, Cotton, Wool, Rubber, and Hides. Metals price index includes Copper, Aluminum, Iron Ore, Tin, Nickel, Zinc, Lead, and Uranium. Fuel price index includes Crude oil (petroleum), Natural Gas, and Coal.
Source: IMF Commodity Price Database November 2012, at http://www.imf.org/external/np/res/commod/index.aspx

The input costs of sub-sectors using metals (basic metals, machinery and equipment, and transport equipment) have not risen to reflect the doubling of the Metal Price Index or the substantial energy price increases (recognising that these are energy intensive sub-sectors). These metal-related sub-sectors have acted to reduce their exposure to commodity price rises – through measures including resource productivity improvements.

This study further examines each sub-sector to determine the extent to which non-labour resource productivity has occurred driven by a range of different activities (energy efficiency, waste reduction, transport efficiency, packaging efficiency, circular resource use and supply chain collaboration), the untapped potential remaining and the barriers that exist to capturing that potential.

Appendix 2: Why Non-Labour Resource Productivity is a Revolution

Acting early to capture new opportunities brings competitive benefits to companies, provided that the opportunities are created by a long term structural change in the industry, i.e. a true revolution. Responding to temporary trends is counterproductive. How can we test whether the next manufacturing revolution as discussed in this paper is truly a revolution that will not revert?

Thomas Kuhn, in his work The Structure of Scientific Revolutions[351], examined the characteristics of a revolution in science (for which he coined the term 'paradigm shift'). These characteristics have subsequently been proven to apply to other, non-scientific fields[352].

Kuhn identified seven characteristics of a scientific revolution, which appear to be in evidence in the manufacturing sector:

Figure 87: Evidence of a Paradigm Shift in Manufacturing

Features of a Paradigm Shift	Evidence from the Manufacturing Sector
1. Crisis	Economic: Manufacturers are facing substantial price increases driven by constraints on resources including oil, commodities and skilled labour. Externalities such as carbon, water and waste disposal are being priced into the economy causing disruption to conventional production costings. Environmental: Environmentalists believe that rising population, wealth and living standards combined with current manufacturing and disposal approaches mean that we are now living beyond the sustainable carrying capacity of the planet[353]. Social: Changing supplier, customer and consumer needs, including corporate social responsibility. Unemployment.
2. Return to first principles	In response to these challenges, leading companies are rethinking what they make, how they make it, and how they provide it to clients (with solutions across the four areas of Incremental change, Process and System change, Structural change and Core Redesign). The emergence of new business models demonstrates the fresh thinking that is occurring.
3. Better solution of the problems	The analysis in this paper indicates the extent of the benefits of the new resource efficient approach, as does the profitability and growth of pioneering companies like Unilever and Toyota.
4. Resistance	Many companies have preferred to maintain the historical linear production model, despite benefits from changing and the successes of their pioneering peers.
5. Gradual growth of support	Company performance data for most of the seven topics examined show increasing numbers of companies making significant improvements in recent years.

[351] Kuhn, T.S., The Structure of Scientific Revolutions, University of Chicago Press, 2nd edition, Chicago, 1970

[352] Lavery, G.J., Towards an Environmentally Considered Building Design Approach for Architects and Engineers, PhD Thesis, University of Queensland, 1998.

[353] For example: "At our current rate of consumption, the Earth needs 1.5 years to produce and replenish the natural resources that we consume in a single year." WWF, Living Planet Report, 2012, http://www.wwf.org.uk/what_we_do/about_us/living_planet_report_2012/

6. A new perspective that is an irreversible step change	Resource productivity including circular resource use and the new business models that facilitate it create economic, environmental and social benefits. Historically, when one leading company embraces a more efficient approach, similar peers within the sub-sector have followed to maintain market share. This has occurred, for example, in carpet tiles and photocopiers.
7. Incomplete definition of the new approach	The change described has no standard definition or common taxonomy. Interface's Ray Anderson called it "a better way" of doing business[354], Patagonia's Yvon Chouinard calls it "responsible business"[355]. Amory Lovins refers to it as "Factor 4"[356]. None of these are well established terms or have become accepted labels for the change. This report refers to the change as the next manufacturing revolution.

[354] Anderson, R., Confessions of a Radical Industrialist: How Interface proved that you can build a successful business without destroying the planet, 2011.
[355] Chouinard , Y., Stanley,V., The Responsible Company, 2012.
[356] von Weizsacker, E., Lovins, A.B., Lovins, L.H., Factor Four: Doubling Wealth, Halving Resource Use - The New Report to the Club of Rome, 1998.

Appendix 3: The Next Manufacturing Revolution Survey

The Next Manufacturing Revolution Survey, conducted in the second half of 2012, asked respondents (who were staff within UK manufacturers) three sets of questions:

1. A series of quantitative questions about the improvements that they had achieved in resource productivity under the seven topics of energy efficiency, process waste reduction, circular resource use, transport efficiency, packaging optimisation, supply chain collaboration and growth with more resource efficient products/business models. This data was used in the benchmarking, including the creation of the graphs showing improvements over time.

2. Qualitative (yes/no) questions on whether the respondent's company was undertaking specific actions on most of its sites related to the seven topics investigated in this study. Eight questions were asked for each of the seven topics, two each related to Incremental Improvements, Process & System Adjustments, Structural Changes and Core Redesign. This developed a profile of activity amongst UK manufacturers.

3. Respondents were asked to list barriers that they observed in their companies to resource productivity actions.

The survey was open to all companies with a manufacturing presence in the UK and was publicised through the networks of Lavery Pennell and 2degrees. Given the orientation of Lavery Pennell contacts and 2degrees members towards more sustainable solution, it is likely that there was a sample bias towards companies who are performing better than average in resource productivity.

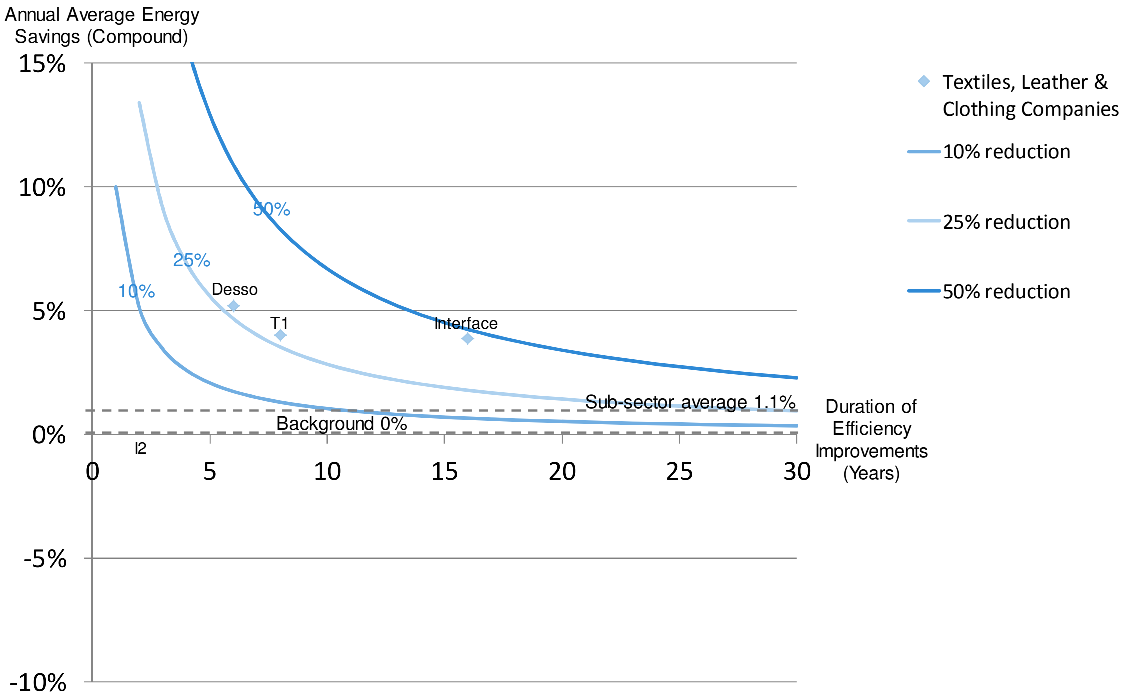
The response was 25 respondents, too small to be a representative sample, but nevertheless useful as one data set to compare with other research.

The results were therefore not used as the basis for this study, but instead were used:

a) As additional data for the benchmark database, checked for consistency against publicly available information where it existed.
b) To present another view on the extent to which companies have adopted Incremental/Process & System/Structural /Core Redesign levels of resource productivity. Given the possible sample bias, the fact that the respondents were likely to exhibit higher levels of adoption than average was recognised by conservatively using the gap to full adoption rather than take-up rates. That is, the percentage of companies who had not adopted specific initiatives from this sample is likely to present a conservative view of the actual proportion of companies left to undertake each action.
c) A further source of input to the barriers discussions.

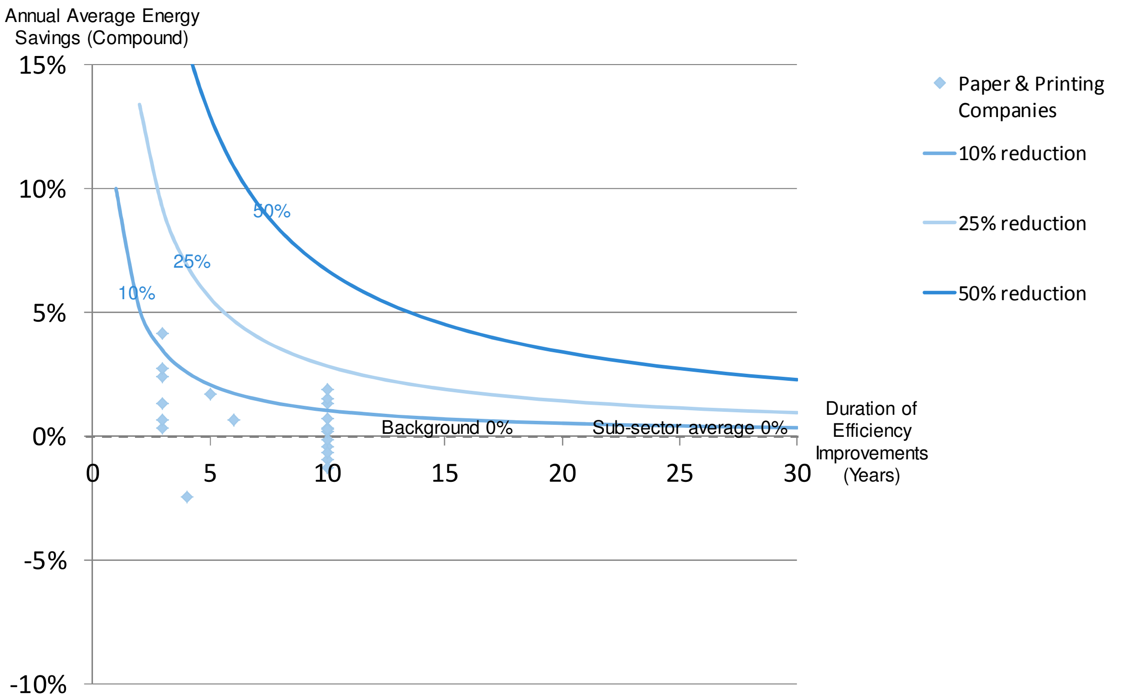
Appendix 4: Energy Intensity Performance Graphs for Sub-Sectors

Figure 88: Energy Intensity for the Textiles, Leather and Clothing Sub-Sector



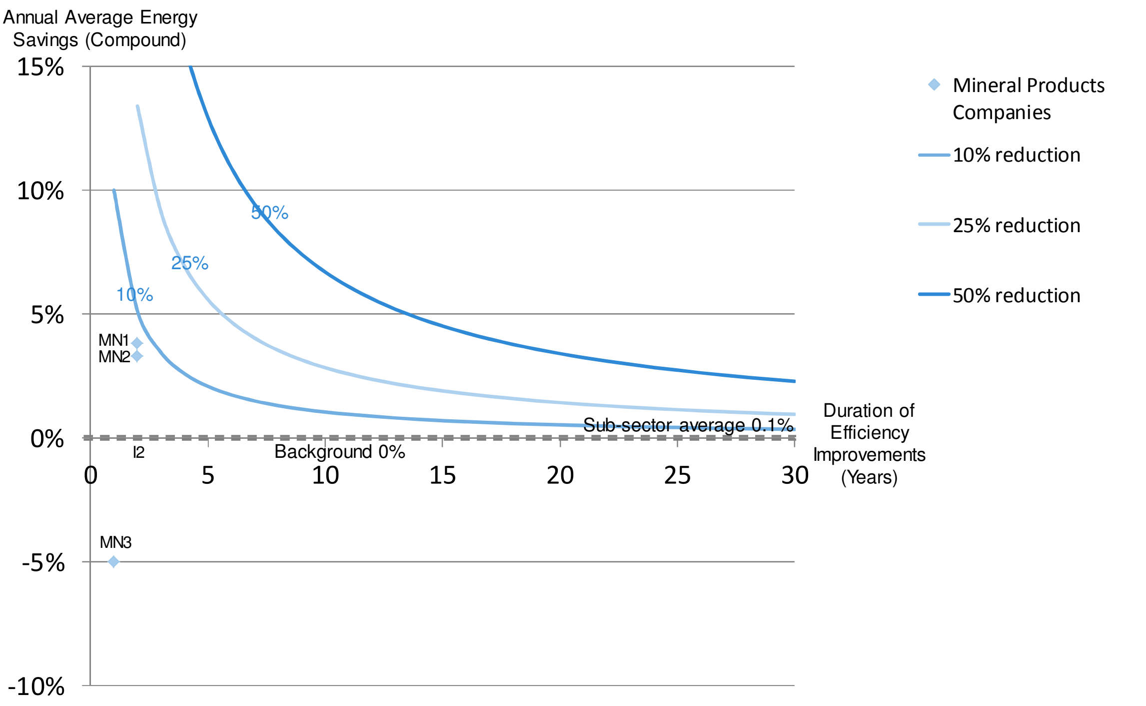
Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 89: Energy Intensity for the Paper, Printing and Publishing Sub-Sector



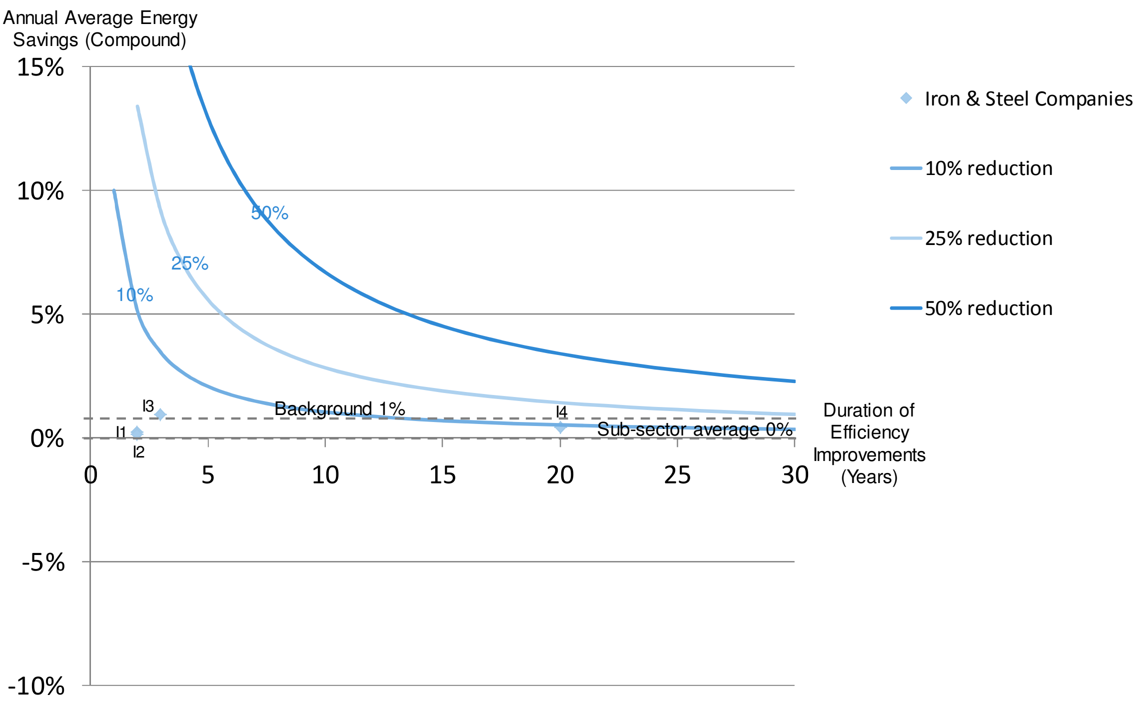
Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 90: Energy Intensity for the Mineral Products Sub-Sector



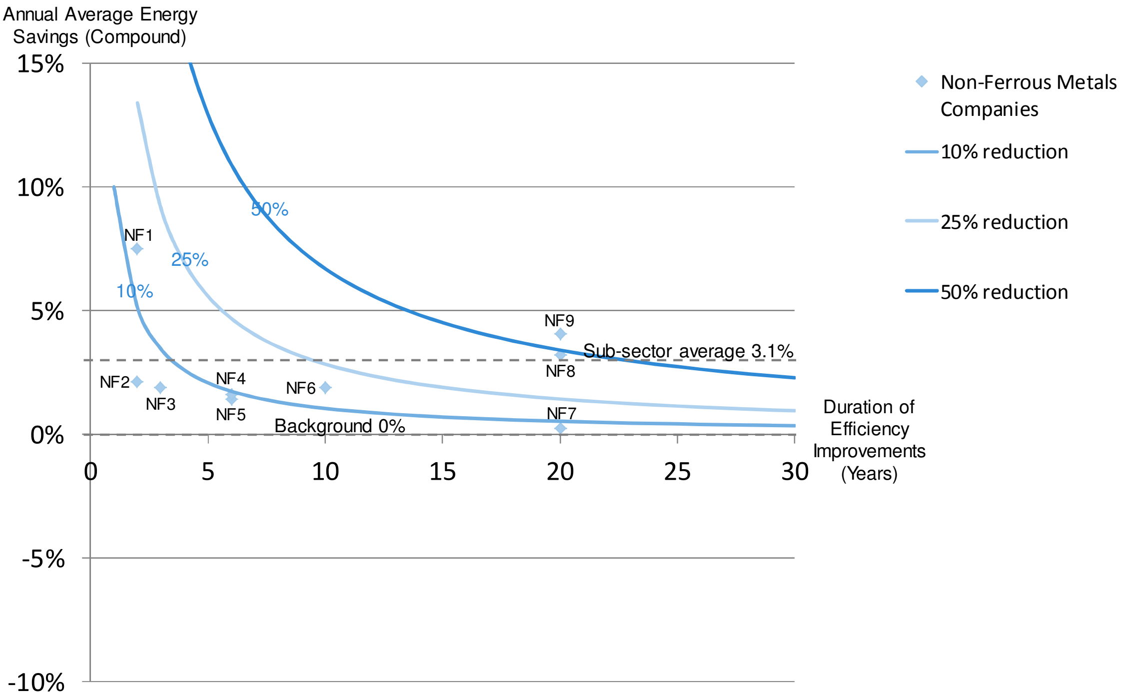
Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 91: Energy Intensity for the Iron and Steel Sub-Sector



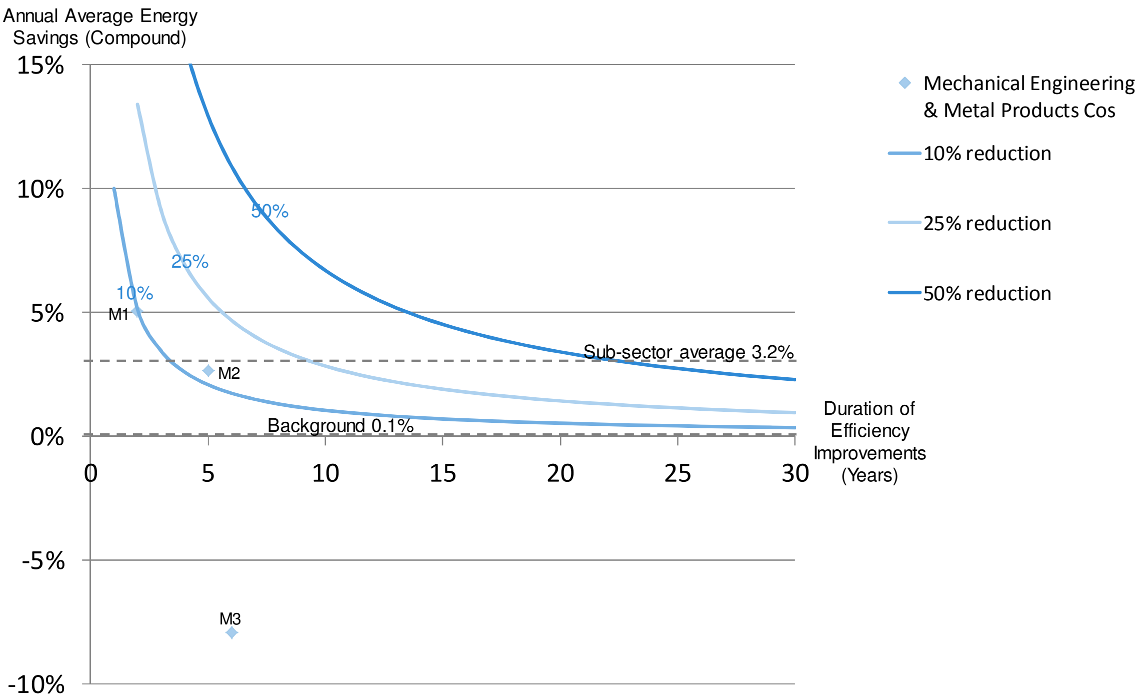
Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 92: Energy Intensity for the Non-Ferrous Metals Sub-Sector



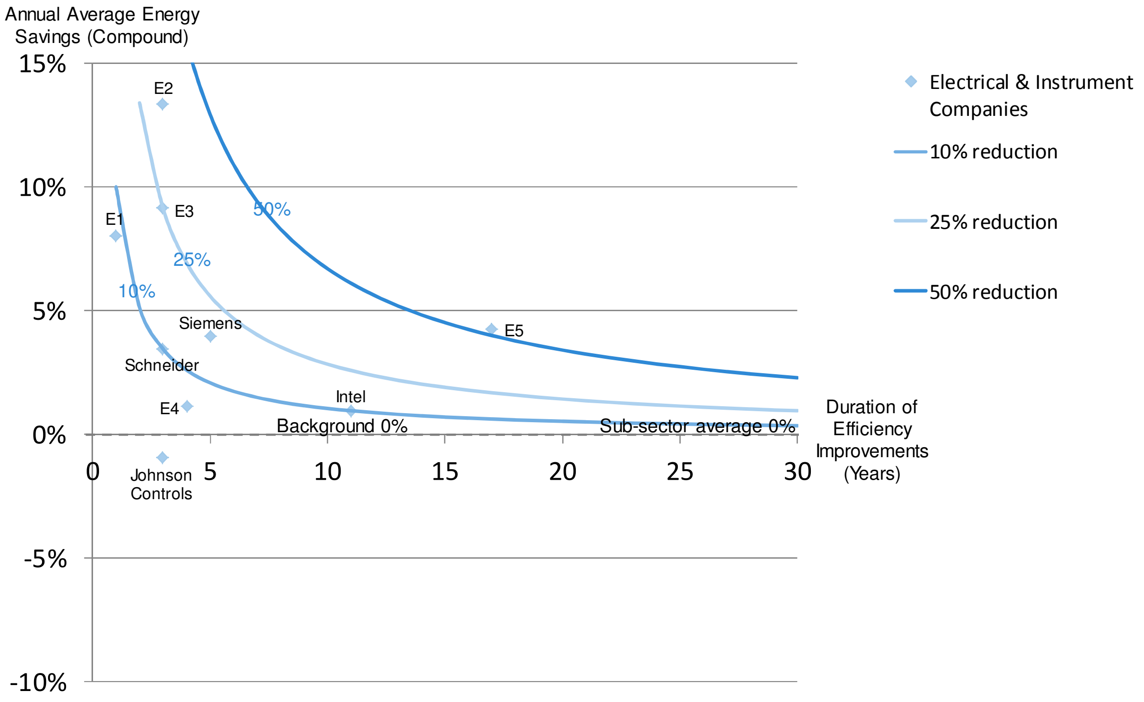
Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 93: Energy Intensity for the Mechanical Engineering and Metal Products Sub-Sector



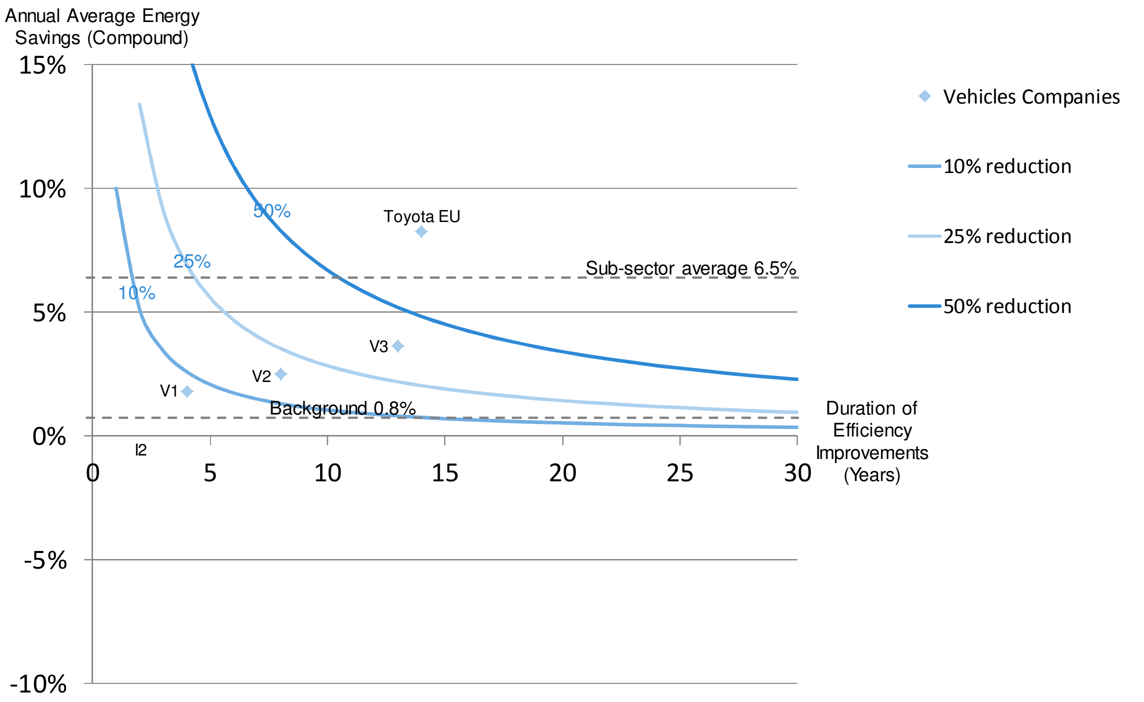
Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 94: Energy Intensity for the Electrical and Instrument Products Sub-Sector



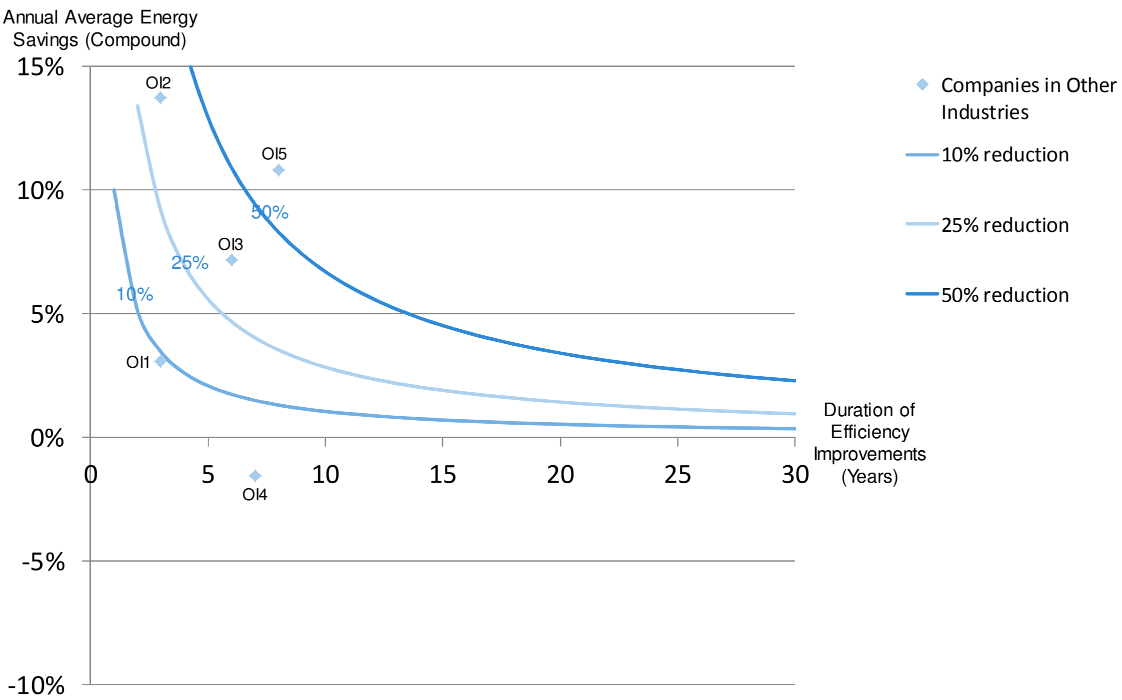
Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 95: Energy Intensity for the Vehicles Sub-Sector



Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Figure 96: Energy Intensity for the Other Industries Sub-Sector



Note: Numbered datapoints are companies who provided data confidentially or are not named for other reasons
Sources: Next Manufacturing Revolution Survey; Next Manufacturing Revolution literature review; Department of Energy and Climate Change, Energy Consumption UK 2010, 2012; Office of National Statistics, Detailed Indices of Production, 2011.

Appendix 5: Methodology for Calculating UK Energy Intensity Improvements

This appendix presents the methodology for calculating UK energy intensity improvements by manufacturing sub-sector and is typical of the approach used to reconcile categorisation differences between data sets. For some chapters, sub-sectors have been grouped because data was not available at a more detailed level.

For the energy efficiency analysis, the SIC Industrial Divisions were reconciled against the sub-sectors used by the Digest for UK Energy Statistics (DUKES) as follows to enable comparison of Index of Production (organised by SIC divisions) and energy consumption (organised by DUKES categories):

Figure 97: Matching of Manufacturing Sub-Sectors

Sub-Sectors Used (from the Digest of UK Energy Statistics, 2011)	SIC Divisions in Categories Used[357]	Equivalent SIC Divisional Groupings or Divisions (SIC 2007)	Divisions Included in SIC Groupings
(a) Food, drink & tobacco	10, 11, 12	CA Food products, beverages and tobacco	10, 11, 12
(b) Textiles, leather, clothing	13, 14, 15	CB Textiles, wearing apparel and leather products	13, 14, 15
(c) Paper, printing, publishing	17, 18	17 Paper products 18 Printing and publishing	
(d) Chemicals	20 21	CE Chemicals and chemical products	20
		CF Basic pharmaceutical products and preparations	21
(e) Mineral products	23 8	23 Non-metallic mineral products	
		8 Other mining and quarrying	
(f) Iron & steel and Non-ferrous metals	24	24 Iron & steel and Non-ferrous metals	
(g) Mechanical engineering & metal products	25 28	25 Metal products	
		CK Machinery and equipment n. e. c.	28
(h) Electrical & instrument engineering	26 27	CI Computer, electronic and optical products	26
		CJ Electrical equipment	27
(i) Vehicles	29, 30	CL Transport equipment	29, 30
(j) Other industries	16 22 31, 32, 33 36, 37, 38, 39	16 Wood and wood products	
		22 Rubber and plastic products	
		CM Other manufacturing and repair	31, 32, 33
		E Water supply; sewerage, waste management and remediation activities	36, 37, 38, 39

Note that the Digest for UK Energy Statistics uses a further 'Unclassified' sub-sector for where a data supplier has been unable to allocate energy between categories and where no additional information is available to DECC to be able to accurately allocate this consumption to an appropriate sub-sector. In 2010, Unclassified represented 11% of the total energy used by UK manufacturing – a significant portion.

Two approaches were examined for dealing with the unclassified figures, with the impact driven by the fact that over the study period of 2002-10, unclassified energy use increased. The first approach determined the rate of improvement from 2002-10 of energy use per sub-sector divided by the

[357] Department of energy and Climate Change, Digest of United Kingdom Energy Statistics (DUKES) 2011, p. 26

corresponding Index of Production without redistributing the unclassified energy. Given the increasing unclassified energy use (some of which may belong to each sub-sector) while energy use in all other categories declined over this period, this first approach results in the most optimistic case of energy intensity reduction over time. Comparing this with best practice will result in the most conservative view of the upside through energy efficiency improvements.

The second approach was to redistribute the unclassified energy on a pro-rata basis, weighted by the energy use of the other categories in each year. Because of the increasing amount of the unclassified energy, this results in a lower rate of energy intensity improvement – likely representing the most conservative view of energy intensity improvement. Comparing this figure with best practice would therefore result in the most optimistic view of the potential savings available.

For 2002 to 2010, therefore, the former approach (without reallocating unclassified energy) was used, in order to provide the more conservative view of the upside potential for energy efficiency improvement in UK manufacturing.

Sub-sector (j) Other Industries includes water supply, sewerage, waste management and water remediation activities which are not related to manufacturing. The energy intensity improvement for this sub-sector was therefore calculated including water and this rate is assumed to apply to all of the manufacturing sectors included in sub-sector (j).

Appendix 6: Avoided Greenhouse Gas Emissions from Process Waste Reduction

The greenhouse gas emissions impact process waste reduction has been calculated comprising two components: (a) Avoided emissions because wasted product did not need to be created, and; (b) Avoided landfill emissions.

a) For those manufacturing sub-sectors where process waste improvements were identified, embodied greenhouse gas emissions were used as follows:
   - Food, drink and tobacco: 2.38 tCO_2e/t embodied greenhouse gas emissions within products[358] applied to a 16% reduction in waste yielding a saving of 2.34$MtCO_2e$ per annum.
   - Wood and wood products: an emissions factor of -1.23 tCO_2e/t of product[359] (negative due to the sequestering of CO_2 by timber – an effect which is considered to be lost when timber is not harvested) applied to the 16% identified opportunity creating -0.29Mtco2e saving every year.
   - Non-metallic mineral products: 0.2 tCO_2e/t of product [360] applied to the further 10% process waste reduction opportunity identified creating a saving of 0.04MtCO2e per annum.
   - Furniture and other manufacturing: 1.36 tCO_2e/t of product[361] with a 5% saving of waste resulting in 0.04 $MtCO_2e$ reduced every year.

b) Avoided landfill emissions, assumed to be relevant only for sub-sectors using biological materials, occur when landfill waste is instead sent to other destinations. For the purposes of these calculations, the waste has been assumed to be sent to anaerobic digestion. Savings in greenhouse gas emissions are:
   - Food, drink and tobacco: Saving 0.5 tCO_2e/t of avoided material sent to landfill[362] resulting in greenhouse gas reductions of 0.12 $MtCO_2e$ per annum.
   - Textiles / wood / paper / publishing: At 1.29 tCO_2e/t of waste send to landfill[363], greenhouse gas emissions savings of 0.33 $MtCO_2e$ every year were identified.

Adding these up results in a greenhouse gas emission benefit of **2.6 $MtCO_2e$** per year, with the majority of this coming from avoided food, drink and tobacco process waste due to its high embodied greenhouse gas emissions.

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[358] Source: WRAP, Waste Arisings in the Supply of Food and Drink to UK Households, WRAP, 2010, p. 70.
[359] Source: Whittaker, C. L., Mortimer, N. D., Matthews, R. W. Understanding the Carbon Footprint of Timber Transport in the United Kingdom, North Energy, 2010, p. 30.
[360] Source: Think Brick Australia, LCA of Brick Products, J/N107884, 2010, pp. 18-19.
[361] Source: Theedom, P. The Embedded Energy Equation, Wider Sustainability, WEEE, Resource 53, at http://www.resource.uk.com/article/Wider_Sustainability/embedded_energy_equation.
[362] Lower end of 0.5 to 1 tCO_2e/t used. Source: Defra, Waste Key Facts and Figures page, http://www.defra.gov.uk/environment/waste/
[363] Timber figure used for all avoided landfilled waste in this sub-sector. Source: Morris, J. Environmental Impacts from Clean Wood Waste Management Methods: Preliminary Results, Seattle Public Utilities, 2008, p. 9.

Appendix 7: Sources of Supply Chain Collaboration Value and their Relationship with Resource Productivity

Figure 98: Relationship between Sources of Supply Chain Collaboration and Resource Productivity

Types of value	Specific sources of value	Examples	Relevance to Resource Productivity
Vertical Collaboration (optimising across supplier and customer)	Demand planning & fulfilment improvement	• Traditional Supply Chain Management	✓ Not additional – represents standard supply chain management practice, which also avoids waste
	Cross-boundary optimisation	• Improved understanding of needs • Process innovation	✓ Can improve energy efficiency, transport efficiency and reduce waste and packaging
	Product innovation	• Identification and development of new solutions	✓ New product development and packaging innovation improves resource productivity - covered in Growth and Packaging chapters
	Reintegration of waste	• Recycling of process waste • Remanufacturing of products post-consumer	✓ Waste reprocessing improves resource productivity – covered in Process Waste and Circular Resource Use chapters
	Risk reduction	• Security of supply (e.g. by improving the viability of suppliers) • Reduced price volatility (e.g. by long term, lower priced contracts)	✓ Many risk reduction actions (e.g. local sourcing) also reduce resource use
	Confidence to invest (i.e. secured future)	• Supplier investing in new equipment and products • Customer investing in supplier	✓ Can improve energy efficiency through investment in better performing equipment
	Improved social and environmental performance	• Improved transmission of corporate responsibility expectations leading to reduced environmental footprint	✓ Can improve energy efficiency, transport efficiency and reduce waste
Horizontal Collaboration (scale of activity across multiple suppliers)	Scale purchasing	• Scale purchasing for all suppliers	✓ Reduces the cost of energy efficient technologies
	Best practice sharing	• Best practice information sharing	✓ Can improve energy efficiency, transport efficiency and reduce waste and packaging
	Investment benefitting all suppliers	• Investment in R&D to improve supplier productivity • Technology investment and pull-through	✓ Can improve energy efficiency, transport efficiency and reduce waste and packaging
	Collaboration amongst suppliers	• Transport sharing	✓ Improves transport efficiency

Appendix 8: Difficulties in Calculating Supply Chain Collaboration Benefits

Some benefits of supply chain collaboration result from suppliers and customers understanding each other's' processes and cost structure - compare the Walkers Crisps example cited above. These types of opportunities are one-off and difficult to estimate systematically for an entire sector or even sub-sector.

Other benefits are difficult to quantify for a range of reasons. For example:

- **Waste reduction in overseas manufacturers.** Lack of transparency into the waste performance of specific manufacturing sub-sectors in specific countries makes calculating the value of avoiding waste difficult. In addition, in most countries landfill costs are significantly lower than in the UK and markets for waste products are at various stages of development.

- **Packaging optimisation by overseas manufacturers**. Substantially less packaging is used when shipping goods between manufacturers than for distribution to end users. Therefore this opportunity cannot easily be quantified.

- **Assisting farmers with distributed energy.** The impact of assisting farmers to adopt distributed energy is difficult to assess because it varies with every situation according to the geography, existing energy prices, cost of capital, scale of generation system, fuel prices/availability, technology used, and the timing of installation. Further, the economic benefits of a guaranteed fixed future energy price for the future are difficult to quantify.

- **Distributed generation.** Substantial installation of CHP has already occurred at UK manufacturing sites, whereas the economics of solar photovoltaic systems on factories and warehouses are currently not compelling enough for large scale deployment. This makes it difficult to quantify the size of the potential economic benefit. However, this opportunity is flagged to be considered on a site-by-site basis (where CHP may already be installed) and over time (recognising that the costs of solar photovoltaic are rapidly decreasing with scale of production and improvements in technology).

Next Manufacturing Revolution

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