A final report by

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RESEARCH & CONSULTING

Business Resource Efficiency

Quantification of the no cost / low cost resource efficiency opportunities in the UK economy in 2014 (Project ID EV0482)

Value-driven consulting *Science-led research*

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Abbreviations

AD	anaerobic digestion
BAU	business as usual
BGS	British Geological Survey
bpd	barrels per day
BRC	British Retail Consortium
BRE	Building Research Establishment
CHP	combined heat and power
CIP	clean in place
CPI	Consumer Price Index
CVM	chained volume measure
DMI	Direct Material Input
DUKES	Digest of United Kingdom Energy Statistics
ECUK	Energy Consumption in the United Kingdom (tables)
EII	Energy Intensity Index
ESOS	Energy Saving Opportunity Scheme
FDF	Food and Drink Federation
FHC	Federation House Commitment
GDP	Gross Domestic Product
GMP	good manufacturing practice
GVA	gross value added
HGV	heavy goods vehicle
LCRS	Logistics Carbon Reduction Scheme
LEAF	Linking Environment and Farming
LED	light emitting diode
LGV	light goods vehicle
LPG	liquid petroleum gas
ONS	Office for National Statistics
PPP	public-private partnership
PRODCOM	PRODuction COMmunautaire (Community Production)
RMC	Raw Material Consumption
SAFed	Safety Assessment Federation
SIC	Standard Industrial Code
SPIRE	Sustainable Process Industry through Resource and Energy efficiency
SRF	solid recovered fuel
tCO_2e	greenhouse gas emissions equivalent to a tonne of carbon dioxide
toe	fuel equivalent to a tonne of oil
UKPIA	United Kingdom Petroleum Industry Association
WRAP	Waste & Resources Action Programme

Units

Conventional SI units and prefixes used throughout: {k, kilo, 1,000} {M, mega, 1,000,000} {G, giga, 10^9} {kg, kilogramme, unit mass} {t, metric tonne, 1,000 kg}

1 tonne oil equivalent = 11,630 kWh

1 Executive summary

This study provides an estimate of financial savings available to UK economic sectors if resource efficiency interventions are made which have no or low cost. In the context of this study, 'no-cost/low-cost' interventions refer to 'quick-win' savings opportunities with a payback of less than one-year.

The focus of the study is on three key resources:

- Energy consumption.
- Raw material consumption or the generation of waste.
- Water consumption.

The study provides a snapshot of savings compared to a 2014 baseline. 2014 is the most recent year in which government statistics on UK waste generation are available. It is noted that this may cause a significant discrepancy between the opportunities outlined in this report for 2014 and the current position in 2017. Where possible, we have included any available information on the trends between 2014 and 2017. This study provides an update to the previous Defra studies undertaken in 2011 using a 2009 baseline, and in 2007 using a 2006 baseline. Where possible the same methodology has been used to enable comparison.

Table 1 provides a summary of the estimated savings from the three studies. The 2014 estimate is in the range of £5.7 billion to £7.2 billion.

Table 1: Estimated no-cost/low-cost resource efficiency savings opportunities in 2006, 2009 and 2014

Resources	Estimated savings opportunity (£ billions)		
	2006 baseline	2009 baseline	2014 baseline
Energy	3.3	3.8	2.3
Waste	2.7	1.9	3 to 4.6
Water	0.4	0.5	0.3
Total	**6.4**	**6.2**[1]	**5.7 to 7.2**

Table 1 shows the overall no-cost/low-cost savings opportunities to be very similar across the three studies with no clear trends. At first glance, this may suggest no real progress was made in resource efficiency over the eight year span of the three studies. However this seemingly flat trend masks significant variations at sector level, with possible savings reducing as resource efficiency opportunities are realised mirrored by the identification of additional savings opportunities through improved data quality. For example, in the food and drink manufacturing sub-sector, the waste savings opportunity fell from £858 million in 2006 to £216 million in 2009 due to a comprehensive programme of work including the Defra Food Industry Sustainability Strategy (FISS) and the WRAP Courtauld Commitments. Conversely,

[1] Note: the overall estimated savings reported in the 2009 baseline study was £22.6 billion which included an £18.3 billion waste saving. This is considered an extreme overestimate of the actual practical no cost / low cost savings opportunity due to the use of a data source that calculated the aspirational 'quick wins' using a hypothetical modelling methodology. To enable a like-for-like comparison this data source was removed from the results shown in Table 1.

the waste savings opportunities identified in the hotels sub-sector (hospitality and foodservice) increased from £70 million in 2006 to £250 million in 2014. This was predominantly due to a study by WRAP in 2013 which quantified and classified the waste generated in the sub-sector and identified the true cost of waste and the associated savings opportunity in this sub-sector.

As set out in the introduction, the opportunities identified in these surveys represent a spotlight on a narrow band (no-cost/low-cost) of the total opportunities available for more effective resource management within the UK economy. Other interventions include Capex projects with a payback of over one year, technical solutions using such techniques as 'lean' manufacturing and broader circular economy type interventions, such as changing to more business models based on 'servitisation' through remanufacture, refurbishment or repair.

Many of the policy interventions that have successfully delivered improved resource efficiency, and in some cases are continuing to do so, have followed a similar three-step process, namely; set a baseline year, set reduction targets and regularly monitor performance. Policy interventions that successfully adopted this approach are:

- For energy, the Climate Change Agreement (CCA), focused on the high energy intensive industrial sectors and the Logistics Carbon Reduction Scheme (LCRS) focused on road freight.
- For waste, the WRAP Courtauld Commitment, focused on the food manufacturing and retail sectors and now expanded to the hospitality and foodservice sector.
- For water, the HM Government's 'Greening Government Commitment' with one area of focus being on water consumption in public administration, and the Federation House Commitment (FHC) focused on the food and drink manufacturing sector.

Although much work has been undertaken in this area, waste in the construction sector is still considered a priority area for further work since it is by far the largest waste producing sector, accounting for 120 million tonnes (equivalent to 69%) of the 174.7 million tonnes of non-household waste generated in the UK in 2014. Much of the waste is considered unavoidable and of low value, and hence there has been a focus on improved waste management rather than waste prevention, e.g. the 'halving waste to landfill' initiative run by WRAP. Additionally, Zero Waste Scotland (ZWS) reports the oversupply of materials to construction sites as a major cause of high value avoidable raw material waste with an estimated 13% of materials being delivered to site being unused.[2]

Mining & quarrying, chemicals and the basic metals sectors are considered areas where more information is required, in terms of the waste being generated and the subsequent waste prevention opportunities. This would reduce the levels of uncertainty in the estimates and enable better understanding of the types of resource efficiency and policy interventions required.

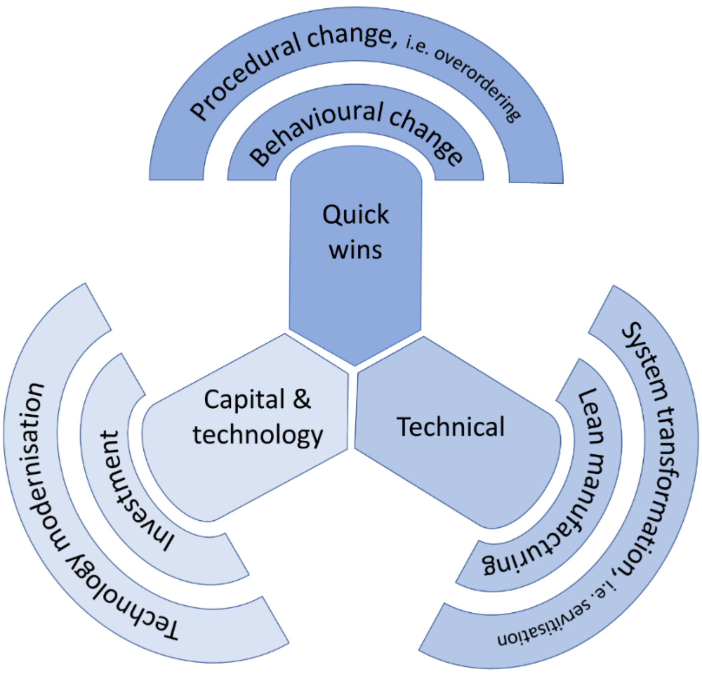
[2] Zero Waste Scotland. The cost of construction waste. Embedding resource efficiency principles in the construction and built environment industries (nd).

2 Introduction

2.1 Resource efficiency

Resource efficiency, in the context of this study, refers to the reduction in the environmental and economic costs associated with the consumption of energy, water and waste generation. In this study we are concerned only with a subset of activities that businesses regard as improving resource efficiency (see Figure 1). This study focuses on the 'quick wins' shown in Figure 1; namely, the changes that require negligible or no financial investment but which reduce the consumption of energy or water or reduce the quantity of waste produced per unit of output. Throughout this report we have used the term 'no-cost/low-cost' and this is defined as conventional resource efficiency interventions with a payback of less than one year, for example switch off or switch on policies for improved energy efficiency. Interventions excluded from the analysis include the more technical 'lean' technology / manufacturing type interventions since these are typically undertaken 'in-house' and hence the results of such interventions are not publicly available and cannot be readily accessed. An exception to this is the Pathway studies undertaken by WRAP. For example, the case study on the Tulip / Co-operative Food pork supply chain reported realised savings within the first year of £395,000.[3] Additionally, the capital- and technology-based resource efficiency interventions are also excluded since access to capital is considered a major barrier to the uptake of such resource efficiency interventions for many businesses.

Figure 1: The three types of resource efficiency interventions



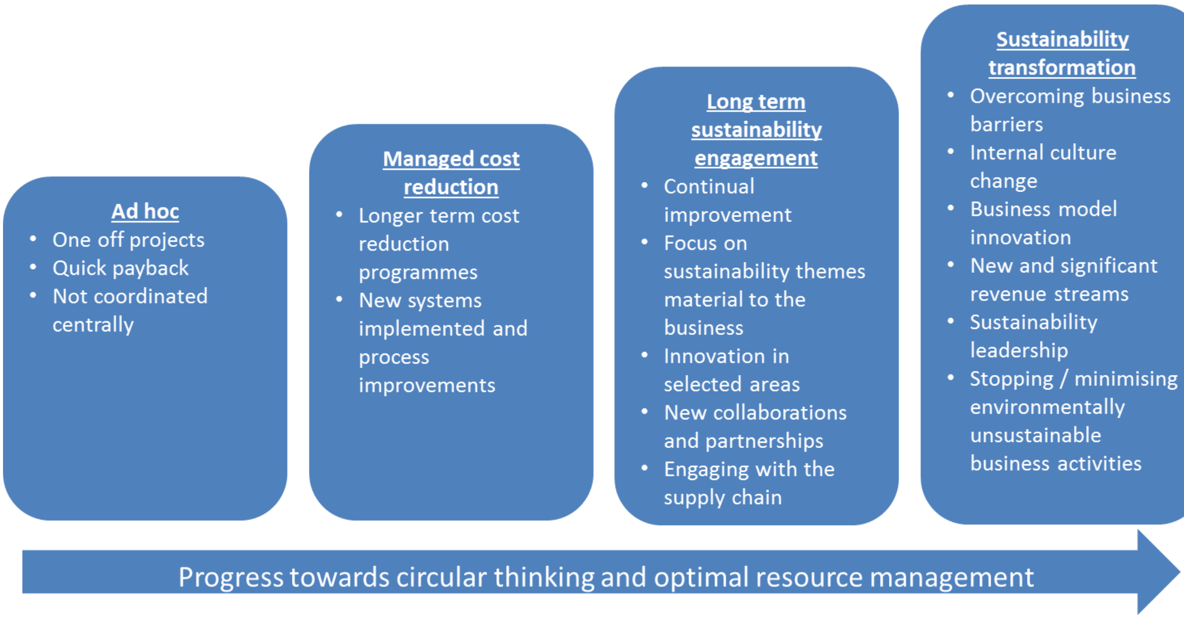
Source: Oakdene Hollins

[3] WRAP. Collaboration in the pork supply chain saves £395,000 and identifies further opportunities. March 2016.

2.2 The broader concept of resource efficiency

Figure 2 provides examples as to how businesses might evolve towards broader thinking around resource efficiency; moving from an 'ad hoc' approach to a full 'sustainability transformation'.

Figure 2: Progressing towards improved resource efficiency



Source: Oakdene Hollins

The concept of the circular economy has established a vision for what a sustainable economy might look like and how the agenda for resource efficiency can be taken forward. The circular economy sets the ambition for an economy without waste, in which products are designed to be retained in the economy for as long as possible. Practical delivery in this area has real advantages in improving the quality and volumes of secondary materials, bringing with it improvements in resource security, reduced import dependency and possibly cheaper raw materials. Benefits in terms of climate change and water use do, in many cases, accompany moves towards greater circularity, these benefits should not always be assumed unless the decision making has been underpinned with scientifically-based research.

There are many differing concepts and approaches that link to the circular concept, such as cradle-to-cradle, zero waste, resource efficiency, reuse and remanufacturing. Each tackles aspects that can lead to a more sustainable economy. Each has a range of merits, principles, methodologies, and complexities. Whatever the terminology or approaches that are adopted, steps that lead to effective resource management with associated reductions in fossil fuel and water consumption will be part of the UK economic mix that attracts investment, supports innovation and delivers jobs over the next few years.

2.3 The benefits of resource efficiency

Resource efficiency is often defined as 'doing more or the same with less'. Improving resource efficiency has three key benefits:

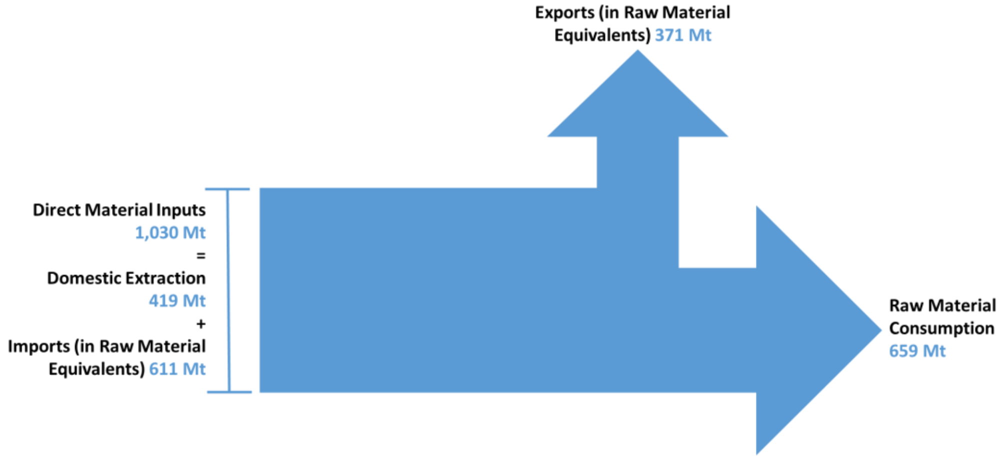
- Doing more with less brings financial benefits. This can impact positively on the profitability of individual companies, sectors and, by extrapolation, the UK economy as a whole. This can have a knock-on effect on competitiveness, economic growth and total economic output.
- Doing more with less may result in a less resource-intense economy.
- Using less material might reduce UK imports.

All three outcomes are clearly of significant advantage to the UK economy and the environment. Analysis in this report demonstrates that there are still considerable savings to be made if no-cost/low-cost solutions are adopted by more players in key industry sectors.

2.4 UK material flows

Figure 3 provides a summary of the material flows in the UK in 2013. This shows direct material inputs (DMI) of over one billion tonnes (1,030 million tonnes), with a heavy reliance on imports accounting for 611 million tonnes of the (59.3%) of the DMI. Raw material consumption (RMC), referring to the consumption in the UK, was 659 million tonnes or 64% of DMI with the remaining 36% being exported.

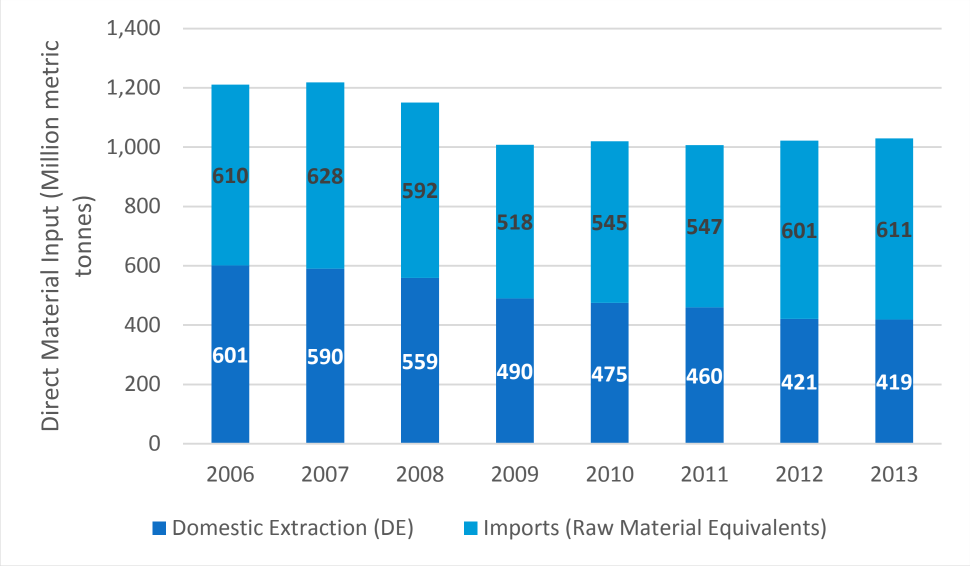
Figure 3: Summary of material flows in the UK in 2013



Source: Office for National Statistics, UK Environmental Accounts

Figure 4 shows the DMI in the UK between 2006 and 2013. This shows a reduction of over 180 million metric tonnes from 1,211 million tonnes in 2006 to 1,030 million tonnes in 2013, with the main cause being the economic downturn in 2008.

Figure 4: Direct material inputs (DMI) in the UK 2006-13

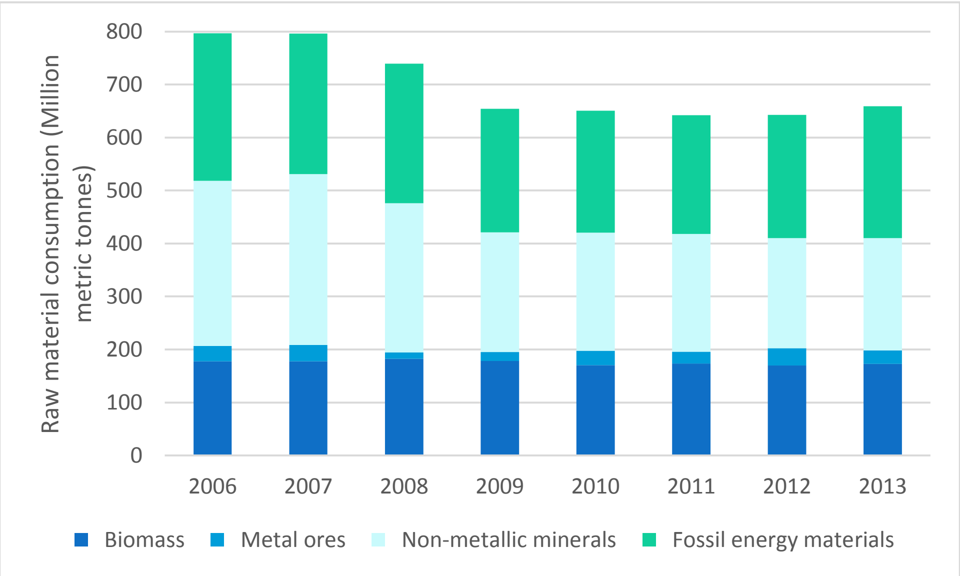


Source: Office for National Statistics, UK Environmental Accounts

Figure 5 shows the breakdown of RMC in the UK by material type. This shows that 'fossil energy material' (248.8 million tonnes in 2013) has overtaken 'non-metallic minerals' (212.4 million tonnes in 2013) as the most consumed material type. 'Fossil energy material' is also the most significant import stream, accounting for 323.1 million tonnes of the total 611.3 million tonnes imported. This potentially impacts on energy security and motivates energy efficiency activities.

Critical raw materials in raw, semi-manufactured and finished products is another high resource risk area due to the heavy dependency on imports. This will not be seen in charts like Figure 5 since it is a low volume (albeit high value) resource.

Figure 5: Raw material consumption in the UK 2006-13



Source: Office for National Statistics, UK Environmental Accounts

2.5 Material consumption and economic activity

Resource productivity is the measure used to determine the relationship between economic activity and consumption. The Office for National Statistics (ONS) reports[4] that at a national level, it is calculated by dividing gross domestic product (GDP) by domestic material consumption (DMC). Table 2 provides a summary of the productivity indicators for the UK reported on Eurostat. This shows that for all three resources (materials, water and energy) productivities showed a gradual improvement over time.

Table 2: Summary of resource, water and energy productivity in the UK 2000-15

Year	Resource productivity	Water productivity	Energy productivity
	EUR per kg Chain Linked Volumes 2010	EUR per cubic metre	EUR per kg of oil equivalent
2000	2.12		6.8
2005	2.46	174.3	7.7
2010	3.18	221.8	8.6
2012	3.35	229.5	9.2
2013	3.37		9.5
2014	3.35		10.4
2015	3.51		10.6

Source: Eurostat, resource efficiency indicators

2.6 Report focus and format

This study represents an update of two previous Defra studies, undertaken in 2011 with a 2009 base year, and 2007 with a 2006 base year.[5,6] This study provides an estimate of the resource efficiency savings opportunity in 2014. Where possible, the same methodology as that used in the previous studies was used to enable a comparison of the three datasets to be undertaken. The main focus of this and the previous two studies is in two areas:

- At source waste prevention: The aim here is to reduce the levels of direct material inputs.
- Recycling: The aim is to increase the levels of secondary raw materials being used in place of the primary raw materials.

The following three sections of this report focus on each of the three resources, namely: energy (Section 3), waste (Section 4) and water (Section 5). Each section is split into four sub-sections:

- Savings: The estimated savings opportunity, revised from previous reports for 2014.
- Data analysis: Uses government statistics to determine the change in output and intensity[7] by sector from 2009 (the base year of the previous study) and 2014 (the base year of this study).

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[4] Office for National Statistics. UK Environmental Accounts: How much material is the UK consuming? 29 February 2016.

[5] Defra 2011. The further benefits of business resource efficiency. Oakdene Hollins, March 2011.

[6] Defra 2007. Quantification of the business benefits of resource efficiency, March 2007.

[7] 'Output' refers to production output. 'Intensity' refers to production output per unit of energy, waste or water consumption, where high intensity refers to a high resource efficiency.

- Supporting evidence: For the sectors and resources representing the most significant resource efficiency opportunities in the 2011 study, literature reviews were undertaken to identify any supporting material that can be used to improve the robustness of the estimates for 2014.
- Previous studies: Provides a summary of the savings opportunities identified in the 2011 study.

3 Energy

3.1 Quantification of the energy savings opportunities in 2014

Based on 2014 UK energy data, energy efficiency saving opportunities of £2,300 million have been estimated to be achievable as a result of no-cost/low-cost actions.

The sections below outline the methodology used, and supporting evidence drawn on, to arrive at this estimate. In addition there is a summary of the findings of the two previous reports based on 2006 and 2009 data.

3.2 Methodology

The methodology used to estimate the value of energy savings at an economy-wide level are based on two key sources of information:

- Snapshot studies looking at energy efficiency in specific sectors.
- Estimates based on economic output trends and sector-level energy consumption data.

Based on the learnings from the previous studies it was concluded that snapshot or sector driven studies frequently provide the best source of information, especially in a topic area such as resource efficiency where there is much research activity and hence they generally provide more relevant, accurate and reliable data. By contrast, official government statistics can be generic and have to be 'shoe-horned' into sector-wide estimates.

The following steps were taken:

1. Analysis of the BEIS (Department for Business, Energy and Industrial Strategy) energy consumption UK (ECUK) statistics to determine the trends in energy use between 2009 and 2014. 2009 was chosen as a starting point because this was the base year of the previous (2011) study.
2. Determination of the causative factors for any changes in energy use in the sectors using most energy (determined in Step 1). This involved the use of the output / intensity datasets produced by ECUK which attribute changes in energy consumption between changes in production output and changes in energy efficiency, measured as, energy consumption per unit of production. It is noted that this analysis should be treated with a degree of caution since the 2011 study found that the use of gross value added (GVA) as the economic output measure generated some very questionable results.
3. Undertaking a literature review to identify any supporting evidence. Part of this review included an assessment of the practical / aspirational nature of the evidence. This was considered a critical component of this study since this was not undertaken in the previous (2011) study and resulted in a gross overestimate of the practical savings opportunity.
4. Quantification of savings opportunities.

3.3 Sector-level analysis of energy consumption in the UK since 2009

3.3.1 *Road freight*

Freight vehicles, consisting of heavy goods vehicles (HGVs) and light goods vehicles (LGVs), make up only 10% and 1.3% respectively, of the 37 million vehicles licensed in the UK.[8] Nevertheless, they are responsible for approximately 35% of the fuel consumed by road transportation in the UK.[9]

One major change from the previous report was made to the methodology for estimating the resource efficiency savings in the freight sector: the HGV and LGV energy consumption recorded in the 'Energy Consumption in the United Kingdom' (ECUK) tables was taken as the total energy consumption in the sector. In the 2011 report, trucks categorised as 'mainly own account' (i.e. trucks owned by the companies with freight to be transported) were assumed to have been excluded in the ECUK data and were added in. However, BEIS confirmed that the ECUK transport tables include all trucks, regardless of ownership, and that energy consumption is based on sales of transport fuels.[10]

A time series of the energy consumption due to UK road freight is given in Table 3. The energy, fuel consumption and emissions were calculated assuming the following:

- Fuel consumption in litres converted from tonnes assuming diesel density of 0.832 kg/L and petrol density of 0.745 kg/L. Data on proportion of diesel LGVs from Table 2.02 of ECUK data. HGVs are assumed to all be diesel.
- Conversion between fuel consumption and energy consumption used the conversion factor 1,203 litres of fuel per tonne of oil equivalent (toe).[11]
- Conversion between fuel consumption and carbon dioxide emissions used the conversion factor 2.87 tCO_2 per toe.

Table 3: Summary of energy and fuel consumption in UK road freight 2009-14

Year	Energy consumption (Mtoe)		Fuel consumption (ML)		Emissions ($MtCO_2$)	
	HGV	LGV	HGV	LGV	HGV	LGV
2009	5.8	5.1	6,950	6,110	16.6	14.6
2010	6.0	5.2	7,160	6,240	17.1	14.9
2011	5.8	5.2	6,970	6,280	16.6	15.0
2012	5.8	5.3	6,980	6,340	16.7	15.1
2013	5.8	5.3	7,010	6,410	16.7	15.3
2014	5.9	5.5	7,100	6,660	16.9	15.9

Source: Road freight statistics 2015, Tables RFS01 and RFS02, Department for Transport, issued August 2016.

Figure 6 provides a summary of the change in output and intensity of the UK road freight sector between 2009 and 2014. The analysis shows that the overall energy consumption by road freight in the UK has increased by 6%. Road freight output, in terms of billion tonne kilometres, increased by 9% over the same period and intensity improved by 2%. For the

[8] VEH0101 table: DfT statistics

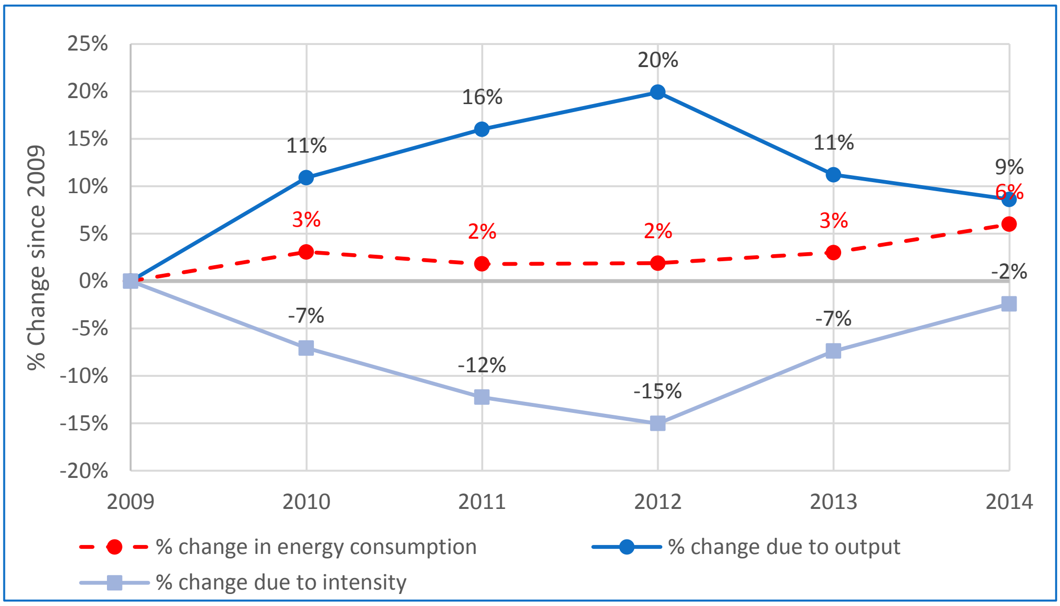
[9] Table 2.02 ECUK data 2016

[10] Personal communication, January 2017

[11] DECC guidelines to Defra (2010), DECC's GHG conversion factors for company reporting

purposes of this study 'intensity' is the most significant factor since it is a measure of energy efficiency and the 2% improvement translates into a direct improvement in efficiency.

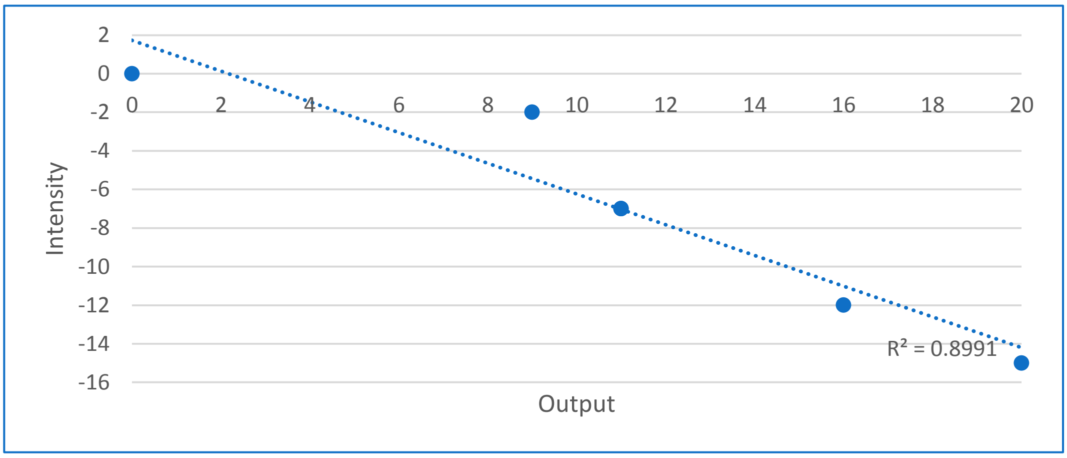
Figure 6: Change in output (billion tonne kilometres) and intensity (%) in UK road freight sector 2009-14



Source: Oakdene Hollins workup of energy consumption and output data from the freight sector (ECUK data, 2016 edition, Tables 2.01, 2.02 and 2.05 and DfT data, 2016 edition Tables RFS0118 and RFS0101)

Figure 6 shows a distinct correlation between output and intensity, i.e. intensity improves with an increase in output. Figure 7 shows the straightline plot of intensity versus output and the strong correlation between the two. This is due to the key measure being vehicle utilisation rates: fleet sizes cannot be readily switched on or off and the same journeys will often be required irrespective of the demand, and hence the lower the demand (output) the lower the vehicle utilisation rates and hence the lower the intensity. This strong correlation, which results in the significant variability in intensity shown in Figure 6, can obscure any real efficiency gains that have been realised over the period 2009 to 2014.

Figure 7: Correlation between output and intensity in the UK road freight sector



Source: Oakdene Hollins workup of energy consumption and output data from the freight sector (ECUK data, 2016 edition, Tables 2.01, 2.02 and 2.05 and DfT data, 2016 edition, Tables RFS0118 and RFS0101)

Three potentially significant factors were explored to identify the impact they had on intensity between 2009 and 2014, namely: fuel efficiency, loading efficiency and changes in the type of vehicles used (Table 4 and Table 5). The key observations are:

- HGV fuel efficiency over the time period fluctuated significantly, with no clear trend over the five years.
- The loading factors for HGVs increased significantly over the time period with a clear upward trend and an 8.5% increase over the five years.
- The number of LGVs in the UK increased by 9% between 2009 and 2014. Considerably more fuel efficient than HGVs (25-40 mpg compared to <8 mpg), the switch to LGVs for local journeys would have contributed to the improved energy intensity. The purchase of new vehicles, however, is clearly not a no-cost/low-cost intervention.

Table 4: Possible causative factors for the change in road freight energy intensity: HGVs

	2009	2010	2011	2012	2013	2014
Average fuel efficiency of HGVs, weighted by bn tonne km*	7.75	7.73	7.99	7.77	7.71	7.82
Cumulative % change in HGV fuel efficiency	0.0%	-0.3%	3.1%	0.2%	-0.5%	0.9%
Loading factors for HGVs**	0.59	0.62	0.63	0.63	0.62	0.64
Cumulative % change in HGV loading factors	0.0%	5.1%	6.8%	6.8%	5.1%	8.5%

*Sources: *DfT Tables RFS0141 and RFS0107, ** DfT Table RFS0117*

Table 5: Possible causative factors for the change in road freight energy intensity: LGVs

	2009	2010	2011	2012	2013	2014
Number of LGVs in the UK ('000s)†	3,275	3,298	3,340	3,373	3,449	3,570
Cumulative % change in LGV number	0.0%	0.7%	2.0%	3.0%	5.3%	9.0%
% of road freight energy consumed by LGVs, in Mtoe††	47%	46%	47%	47%	48%	48%
Cumulative % change in road freight energy consumption due to LGVs	0.0%	-0.4%	1.3%	1.8%	2.1%	3.6%

Sources: † DfT Table VEH0404, †† ECUK Table 2.02

A European Commission 'Survey Report' of energy efficiency policies in the EU Member States[12] in 2015 states that, for the transport sector in the UK, a focus on alternative fuels rather than on energy efficiency improvements is reported. This follows the general observation made by the experts in the survey that, across all sectors in the UK:

"Present policy and decision makers do not see energy efficiency as an opportunity and focus on supply side."

[12] European Commission 2015, Survey Report 2015. Progress in energy efficiency policies in the EU Member States – the experts perspective.

However, the Logistics Carbon Review 2016[13] reports that the companies that had voluntarily signed up for the Logistics Carbon Reduction Scheme (LCRS) had reduced their average emissions per vehicle km from 0.75 $kgCO_2e$ in 2009 to 0.71 $kgCO_2e$ in 2014, i.e. a reduction of 5.3%.

The Centre for Sustainable Road Freight (SRF) completed a study in December 2015 assessing the potential for demand-side fuel savings in the HGV sector. Three no-cost/low-cost opportunities identified in the study were: driver training, driver performance monitoring, and logistical measures.

i. Driver training

Using the average savings made for drivers undertaking training as part of the government-sponsored Safe and Fuel Efficient (SAFed) programme, it is estimated that long-haul journeys save 9%, urban journeys 5% and regional journeys 7% in terms of fuel efficiency improvements. The payback period for most companies on the course is less than two years and hence for this study - in which no-cost/low-cost is defined as having a payback of less than one year - it is considered appropriate to halve the estimated saving, making an average saving of 3.5%.

The take-up rate was 8% in 2010, and the SRF study estimates that this could rise to 67% by 2030. In the context of this study, this take-up rate of 67% by 2030 is considered the limit of the no-cost/low-cost intervention opportunities since it is acknowledged that some freight operators will not be receptive to such a training programme. The increase in take-up rate between 2010 and 2030 is reckoned at 59% which equates to an annual take up rate of 2.95%. It is therefore estimated that the take-up rate in 2014 would have been 19.8% and the no-cost/low-cost savings opportunity remaining would have been 1.65%, i.e. 3.5% x (67% - 19.8%).

ii. Driver performance monitoring

The SRF study reports that monitoring employees' behaviour is key to maintaining improved performance, and that a 4-5% fuel saving is a realistic savings opportunity for a company with a good record of fuel management and driver training. For this study the upper limit of 5% is considered appropriate. In 2010 the uptake of driver monitoring was 8% and, like driver training, this could rise to 67% by 2030. It is therefore estimated that the take-up rate would have been 19.8% in 2014 and the savings opportunity remaining would have been 2.36%, i.e. 5% x (67% - 19.8%).

iii. Logistical measures

The SRF study reports that reducing empty running time, through backhauling, can result in an 8.2% reduction in fuel use. Based on the 2010 uptake of 66% and the expectation that this could rise to 79% by 2020, it is estimated that a 1.1% no-cost/low-cost savings opportunity remained in 2010, i.e. 8.2% x (79% - 66%). The SRF study suggests that the opportunity (79%) can be fully realised by 2020 which equates to an annual realisation rate of 0.11%, and hence in 2014 0.63% of the savings opportunity remained.

The SRF study states that a significant barrier to realising a reduction in empty running times is the need for sector-level collaboration, since interventions such as back-haul and

[13] Logistics Carbon Review 2016, incorporating the sixth annual report of the logistics carbon reduction scheme (covering 2005-2014)

synchronised consolidation require common standards of load description - in particular the availability of weight and volume data.

Summary for road freight sector

The three interventions described above represent a combined savings opportunity of 4.6% (driver training 1.65%, driver performance monitoring 2.36% and logistical measures 0.63%). This would appear to show that around 6.4 percentage points of the 11% savings opportunity estimated in the 2011 study had been realised. This is in line with the progress reported in the 2016 Logistics Carbon Review in which a members reported a saving of 5.3% between 2009 and 2014. For the purpose of estimating the no-cost/low-cost savings opportunity for 2014, it is considered appropriate to use the realisation rate contained in the Logistics Carbon Review of 5.3% since this considered all no-cost/low-cost interventions. This would suggest that the savings opportunity remaining in 2014 is 5.7%, i.e. the 11% saving identified in the 2011 report minus the 5.3% realisation rate.

Table 6 summarises the estimated savings in 2014. Because 'mainly own account' freight is not now added in and the overall opportunities have halved since 2009, the total estimated savings from freight have decreased from £2,756 million to £750 million (i.e. by 75%).

Table 6: Summary of estimated savings opportunities for the road freight sector in 2014

	Total energy consumption 2014 (ktoe)	Low-cost savings opportunities				
		Saving opportunity (%)	Energy consumption (ktoe)	Fuel consumption (million litre)	Emissions ($ktCO_2e$)	Financial (£M)
Road freight	11,400	5.7	650	796	1,860	750

Source: Oakdene Hollins workup based on ECUK data, 2016 edition, Tables 2.01, 2.02 and 2.05 and DfT data, 2016 edition Tables RFS0118 and RFS0101

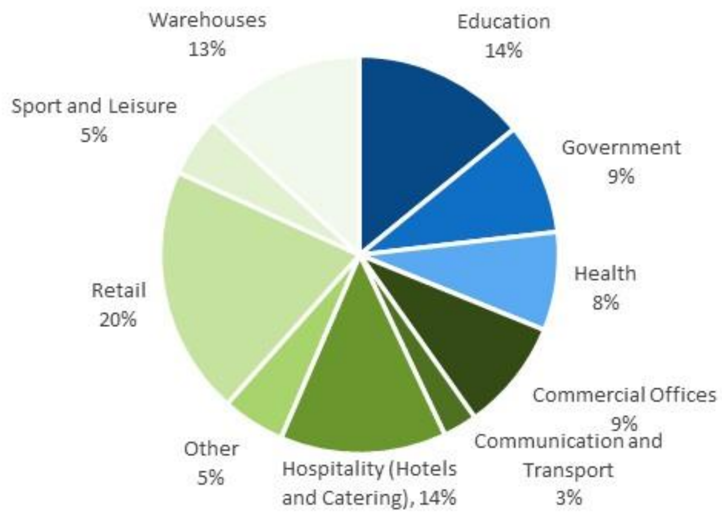
Note on fuel price: In the previous study a minimum economic level of savings opportunity was based on the price of bulk diesel and the maximum based on average forecourt prices for diesel including VAT. In this study, only the price of wholesale bulk diesel will be considered, which in December 2014 was 94.18 pence per litre.[14]

3.3.2 Commercial services sector

Commercial services accounted for over two-thirds of the 18.1 million toe of energy consumed by the UK services sector in 2014. Retail was the biggest energy consumer, followed by hotels and catering, education, and warehouses (Figure 8). Combined, these four sub-sectors accounted for 61% of the service sector's energy consumption.

[14] FTA logistics report 2106 (http://www.fta.co.uk/export/sites/fta/_galleries/downloads/logistics_report/lr16-web-030616.pdf)

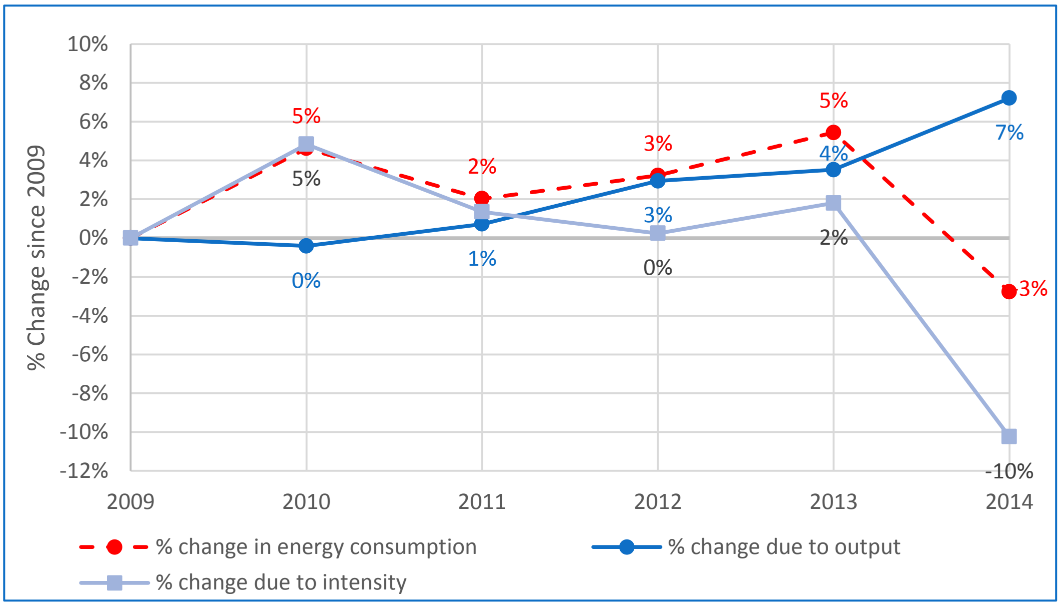
Figure 8: Energy consumption in the commercial services sector in 2014



Source: ECUK data, 2016 edition, Table 5.05

Figure 9 shows the change in energy intensity and output in the service sector between 2009 and 2014. Between 2009 and 2013 energy intensity was higher than the 2009 base year, but a 10% reduction occurred in 2014. This dramatic improvement in intensity in 2014 is considered a measurement anomaly rather than an actual physical improvement since the sub-sector analysis that follows shows a similar trend in the majority of the sub-sectors. It is therefore recommended that the 2014 results are viewed with a high degree of caution. A full description of the energy intensity and outputs is given in Annex B.

Figure 9: Change in energy intensity and output in the commercial services sector 2009-14



Source: ECUK data, 2016 edition and output per subsector based GVA (ONS) re-indexed to 2009.

In the previous report (covering 2009 data) the opportunities for energy efficiency savings in the services sector were based on how much of the savings identified in the first report (covering 2006 data) were still to be realised. This approach is no longer suitable due to the significant uncertainty in the data. The alternative approach used in this report places greater emphasis on the supporting evidence that was developed by stakeholders in the individual sub-sectors.

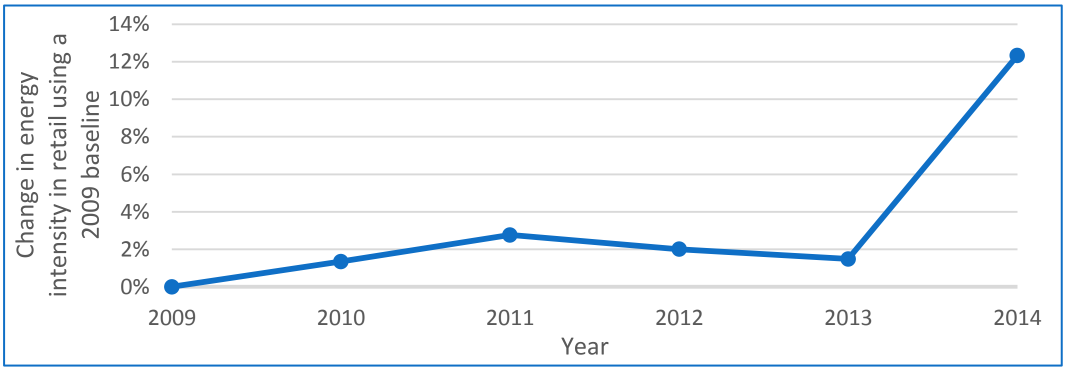
The following sections focus on four sub-sectors of the service sector: retail, education, hospitality and warehouses.

Retail

Figure 10 shows the change in energy intensity in the retail sector and the apparent dramatic improvement in intensity in 2014. Please note: this is normalised for output and the positive change represents an improvement in energy efficiency. This shows a very similar trend to that of the whole service sector (Figure 9) which exhibited a 12% improvement in 2014.

In 2015, 3.29 Mtoe of energy was consumed by the retail sector, according to the most recent release of ECUK data (2016). This is 10% lower than in 2014, despite an increase in output of nearly 5%. This therefore shows that the reported improvement in energy efficiency in 2014 continued forward into 2015 implying that a step change was made in 2014. The nature of the step change could not be determined within the scope of this study.

Figure 10: Change in energy intensity in the retail sector 2009-14



Source: ECUK data, 2016 edition

The British Retail Consortium (BRC) attributes a saving in CO_2 emissions from retail of a third between 2005 and 2012 to its ‘A Better Retailing Climate’ initiative. The BRC has also recently launched an initiative to reduce the emissions of its sector by a further 25% by 2020, relative to 2015 levels, called the ‘25-in-5’ initiative.

Energy costs make up a significant proportion of retailers’ overheads which drives their take-up of energy saving opportunities. Nearly three-quarters of the energy consumed in retail is for lighting, heating, ventilation and refrigeration.[15] Better energy management and equipment maintenance, staff education and the gradual replacement of equipment with more energy efficient models are some of the no-cost/low-cost interventions the BRC

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[15] http://info.utilitywise.com/hubfs/Retail%20White%20Paper%20Jan17.pdf?submissionGuid=497965cb-906f-4cda-88a2-bdfee9846f07

expects its members to implement to reach the 25% emission reduction (and hence energy saving) target set.[16]

Table 7 provides an estimate of the savings opportunity for the retail sector in 2014. Based on the learnings from the previous Defra studies, the estimate assumes that half of the 25% target set by the BRC can be achieved through no-cost/low-cost interventions.

Table 7: Summary of estimated savings opportunities for the retail sector in 2014

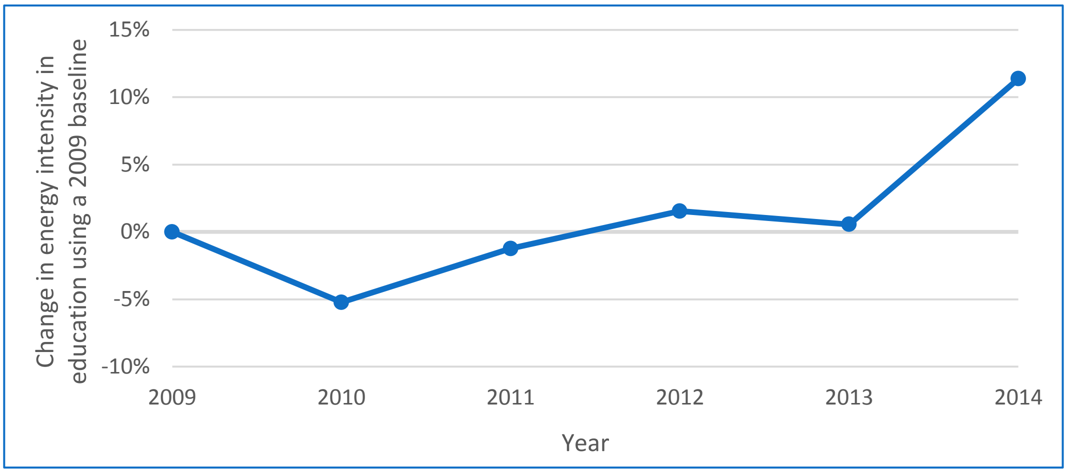
	% services energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Retail	20	3,650	12	445	1,868	326

The tonne oil equivalent (toe) to tCO_2 conversion factor[17] (4.2) and the average p/kWh (6.3) is based on the fuel mix in the sub-sectors in 2014 and the non-domestic energy prices for electricity, natural gas and oil as recorded in DECC's energy price data, June 2016 release, Table 3.1.4 .

Education

Energy consumption in the education sector was reported to be 2.5 Mtoe in 2014, which is 11% lower than in 2009. Figure 11 shows the trend in energy intensity in the education sector with the now familiar change in 2014 (11%), with little or no change observed between 2009 and 2013.

Figure 11: Change in energy intensity in the education sector 2009-14



Source: ECUK data, 2016 edition

In the education sector, including schools and further education facilities, heating can account for over half of energy use. Fuel consumption in the sector is dominated by natural gas (55%), followed by electricity (29%) and oil (9%), and is weather dependent.[18] Efficient

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[16] https://www.carbontrust.com/media/39228/ctv001_retail.pdf

[17] The retail sub-sector relies predominantly on electricity (72%) and natural gas (25%) for their energy needs. Given the energy mix of the sub-sector the toe to tCO_2 conversion factor for retail is 4.2, allowing us to calculate that the retail sector CO_2 emissions in 2014 were approximately 15 million tonnes.

[18] Annual winter energy consumption can vary by 15-20% depending on the severity of the weather. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/208610/the_effect_of_the_cold_2012_13_winter_on_energy_bills.pdf

use and maintenance of the heating systems, often requiring upgrades of older systems, are some of the recommended measures to reduce energy consumption in education facilities. Better insulation of the buildings themselves, including glazing and the installation of draught lobbies, would also contribute, but generally require considerably greater up-front investment[19] and hence cannot be considered no-cost/low-cost interventions. However, larger campuses - such as Universities - would benefit from better monitoring and control of energy consumption as well as better staff awareness, especially for those involved in purchasing energy-intensive equipment[20], and these are considered no-cost/low-cost interventions.

The Carbon Trust estimated in 2012 that the opportunity for energy savings in further and higher education facilities was of the order of 20%. For the purpose of estimating the outstanding no-cost/low-cost opportunities we will assume there are similar saving opportunities to be realised in schools. However, Figure 11 shows that in 2014 energy intensity improved by 11% leaving only half of the energy efficiency savings identified by the Carbon Trust. Of the energy efficiency opportunities represented by this 10%, we estimate that half of the measures are quick-win no-cost/low-cost in nature, and that the remainder consist of longer pay-back measures which require considerable investment.

This leaves us with a figure of 5% for outstanding no-cost/low-cost energy efficiency opportunities in education, corresponding to potential financial savings of £53 million (see Table 8).

Table 8: Summary of estimated savings opportunities for the education sector in 2014

	Share of services energy use 2014 (%)	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Education	14	2,547	5	127	369	53

The toe to tCO_2 conversion factor (2.9) and the average p/kWh (3.6) is based on the fuel mix in the sub-sector in 2014.

Hospitality

This sector, which includes hotels, pubs and restaurants, has seen its energy intensity improve in 2014 compared to preceding years (Figure 12). The sector has also exhibited considerable growth and was approximately 10% larger (in terms of GVA) in 2014 than in 2009. Energy efficiency savings in the sector are primarily driven by a desire to cut overheads and maintain profits in a competitive market. Industry-led initiatives include the energy benchmarking exercise carried out by Carbon Statement in 2014 and 2016, which looked at the impact of energy efficiency on profitability and environmental performance of managed pub and restaurant chains.[21] Hotels and other tourist accommodation providers are also motivated to improve their energy efficiency by the requirements of labelling schemes such as Nordic Swan and the EU Ecolabel.

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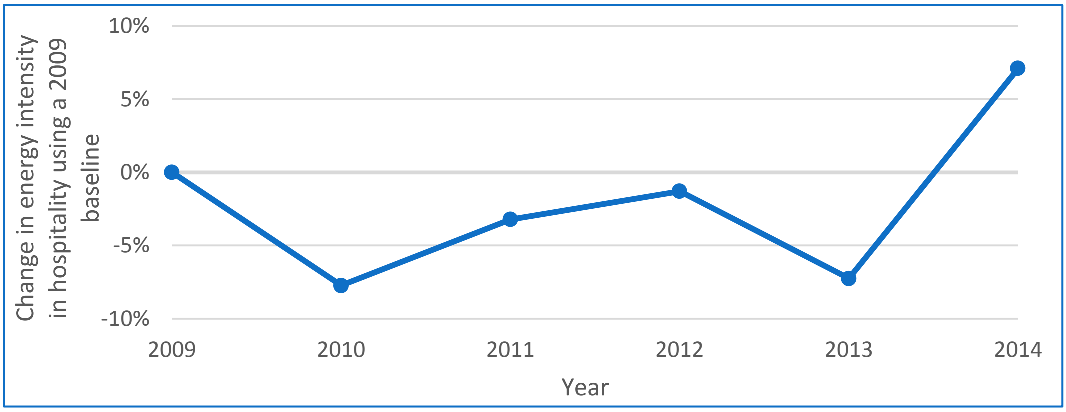
19 https://www.carbontrust.com/media/39232/ctv019_schools.pdf

20 https://www.carbontrust.com/media/39208/ctv020_further_and_higher_education.pdf

21 http://www.carbonstatement.com/hospitality-sector-energy-benchmark-2016/

Figure 12: Change in energy intensity in the hospitality sector 2009-14



Source: ECUK data, 2016 edition

A recent audit of Northern Ireland hotels identified energy and resource efficiency savings opportunities, with paybacks of under 1.5 years, equivalent to approximately 12% of their utility bills. The Carbon Trust estimates that energy consumption in hospitality could be reduced by up to 12-13% with moderate improvements in efficiency and effective use of equipment with payback periods of less than two years. Table 9 provides an estimate of the savings.

Table 9: Summary of estimated savings opportunities for the hospitality sector in 2014

	% services energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Hospitality	14	2,438	12	293	965	143

The toe to tCO_2 conversion factor (4.2) and the average p/kWh (3.3) is based on the fuel mix in the sub-sector in 2014.

Warehouses

Energy consumption by warehouses accounts for 13% of the UK service sector total. The main occupiers of warehouse space are retailers (high street, food and online) at nearly 50% of floor space, but warehouses are also used by transport and automotive companies, wholesalers and mail distributors.[22] Energy in warehouses is used for lighting, heating, air-conditioning and the moving and handling equipment.

Between 2010 and 2013, energy intensity in warehouses was lower than in 2009 (Figure 13). This is likely to be a symptom of the under-utilisation of warehouse space during the recession following the financial crisis. The energy intensity of the sub-sector improved in 2014, though how much of this is due to better warehouse utilisation and how much is due to energy efficiency measures is not clear.

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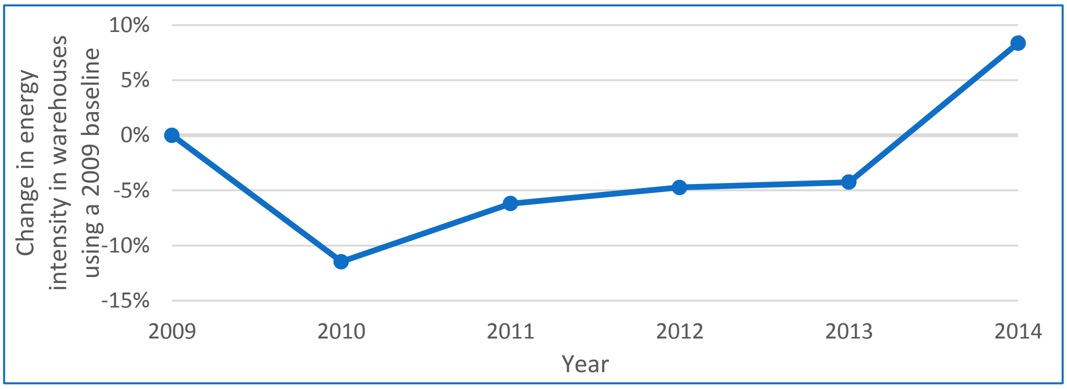
22 http://www.cambridgeshirechamber.co.uk/downloadlibrary/UKWA%20Savills.pdf

Figure 13: Change in energy intensity in the warehouse sector 2009-14



Source: ECUK data, 2016 edition

The type of energy efficiency saving measures relevant to warehouses, and the nominal energy savings they represent, as estimated by an Australian trade association, are included in Table 10.[23]

In the USA, lighting and heating are the main uses of energy in warehousing, with total energy bills, in some cases, accounting for more than 10% of a warehouse's total revenue.[24] There are also case studies highlighting that a change in lighting technology alone can reduce the energy consumption of a warehouse by 40%.[25] Given that there will have already been some roll-out of LED installations and other energy saving measures in UK warehouses by 2014, we assume that the remaining opportunity in this sector is a third less than the 26% estimated in the Australian factsheet, i.e. 17%.

Table 10: Energy efficient savings measures in warehouses

Typical warehouse improvements	Nominal energy savings (% of total site energy use)
Upgrade light fittings	10%
Install lighting controls	2%
Fix compressed air leaks, reduce pressure	3%
Install/improve control system on a/c	3%
Variable speed drives for fans/pumps	2%
Fit ceiling/wall insulation	5%
Improve maintenance	1%

Source: Supply Chain & Logistics Association of Australia

The energy efficiency improvements identified in the Australian fact sheet account for a total of 26% of the total energy use at typical warehouse sites. Most of these opportunities will be similar in UK warehouses, though air-conditioning will be less significant, and heating and insulation more important. Table 11 show the summary of the estimated savings opportunities.

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23 http://sclaa.com.au/energy-efficiency/assets/pdfs/SCLAA_factsheet_No2_2040118.pdf
24 http://dsoelectric.coopwebbuilder2.com/sites/dsoelectricdsoelectric/files/images/Business/warehouses.pdf
25 http://www.nrel.gov/docs/fy14osti/57263.pdf

Table 11: Summary of estimated energy savings opportunities for the warehousing sector in 2014

	% services energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Warehouses	13	2,379	17	404	1,415	230

The toe to tCO_2 conversion factor (3.5) and the average p/kWh (4.9) is based on the fuel mix in the sub-sector in 2014.
Source: Oakdene Hollins workup based on ECUK data, 2016 edition, Tables 5.01 to 5.11

Discussion of the marked increase in energy intensity in 2014 seen in all service sub-sectors

Energy intensity increased in each of the service sub-sectors presented above between 2013 and 2014 as well as in the service sector overall. This could partly be explained by the overall increase in the output of the services sector, of approximately 3.5%, which would lead to a higher utilisation of facilities and increased energy efficiency. Though not shown in the data above, the energy intensity in the service sector in 2015 is similar to in 2014, i.e. 11% and 10% higher than in 2009 respectively.[26]

We also wanted to rule out the effect of temperature variations on the services data. None of the data presented above has been adjusted to reflect the variation, year-on-year, of temperature in the UK. This was because these temperature adjustments were not available for the sub-sector level data we were using, only for the sector-level data. As with domestic demand, there is a strong seasonality to energy demand from the services sector because a high proportion (53% in 2014) of its energy consumption is from heating, cooling and ventilation.

By comparing the weather factors known to correlate with energy demand (see Table 12), we learnt that 2014 was almost identical (within 2%) to 2011 in terms of these indicators. The 11% increase in energy intensity between these two years cannot, therefore, be due to temperature alone.

Table 12: Weather factors that influence energy demand particularly in the domestic and services sectors

Year	Mean air temperatures	Mean heating degree days	Services sector energy consumption if output constant at 2009 levels (ktoe)
2009	10.1	5.7	18,763
2010	9.0	6.8	19,671
2011	10.7	5.0	19,017
2012	9.8	6.0	18,808
2013	9.7	6.2	19,101
2014	10.9	4.9	16,842

Source: ECUK data, 2016 release, Table 1.01

[26] ECUK data, 2016 release, Table 5.05

Summary for the commercial services sector

Table 13 provides a summary of the estimated energy savings opportunities in the commercial sector in each of the four sub-sectors discussed above. Please note: ‘other’ is calculated by grossing up the subtotal for the four focus sub-sectors.

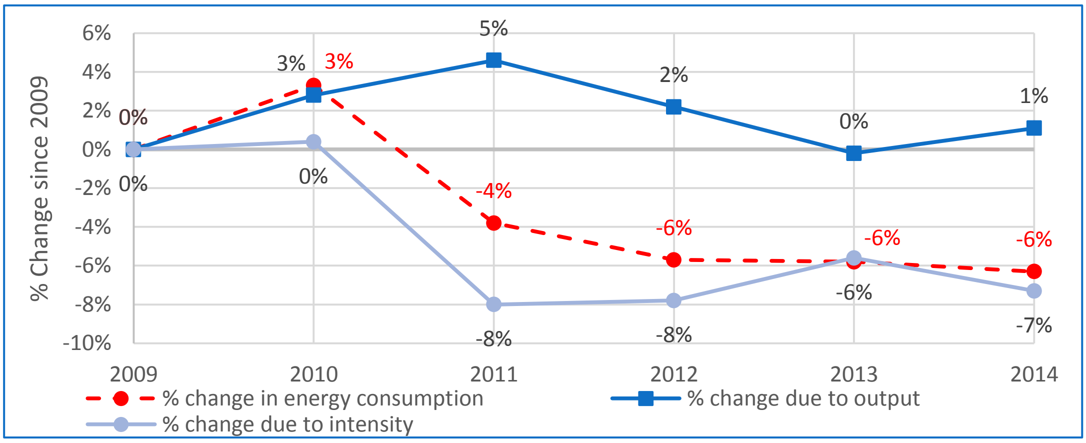
Table 13: Summary of estimated energy savings opportunities in the commercial sector in 2014

	% services energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Retail	20	3,650	12%	445	1,868	326
Education	14	2,550	5%	127	369	53
Hospitality	14	2,440	12%	293	965	143
Warehouses	13	2,380	17%	404	1,415	230
Sub total	**61**	**11,010**	**12%**	**1,269**	**4,617**	**752**
Other	39	7,040	12%	845	2,952	481
Total	**100**	**18,050**	**12%**	**2,114**	**7,569**	**1,233**

3.3.3 *Industrial sector*

The industrial sector consumed 23.8 Mtoe energy in 2014, and Figure 14 shows the trend in output and intensity between 2009 and 2014. This shows that energy consumption reduced by 6% even though output showed a slight increase (1%) due to a 7% improvement in energy intensity.

Figure 14: Change in energy intensity and output in the industrial sector 2009-14

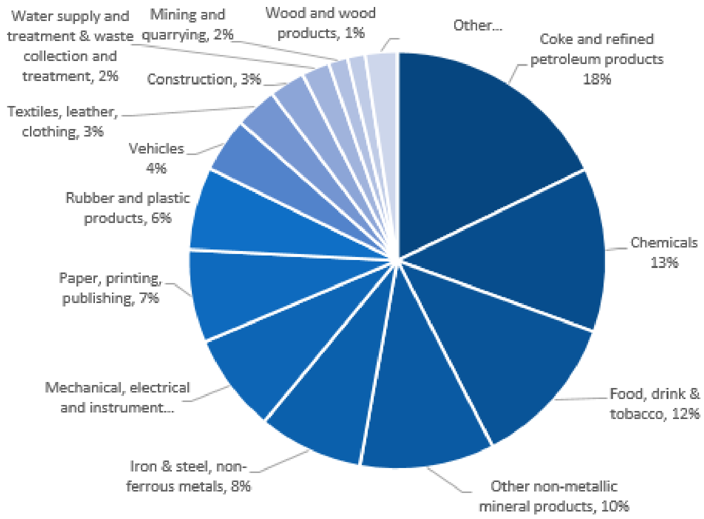


Source: ECUK data, 2016 edition

Figure 15 shows the breakdown by sub-sector. Four sub-sectors account for over half (53%) of the total energy consumed by the industrial sector, namely: coke and refined petroleum; chemicals; food, drink and tobacco; and other non metallic mineral products.

These sub-sectors are discussed in the following section and reviews of seven additional sub-sectors can be found in Annex C.

Figure 15: Industrial energy consumption by sub sector in 2014



Source: ECUK data, 2016 edition, Table 4.03

As with the commercial services sector, the methodology used in the previous study to determine the savings opportunity was considered inappropriate. An alternative approach uses material developed by the Department of Energy and Climate Change (DECC) and the Department for Business, Innovation and Skills (DBIS) in 2015. DECC and DBIS published a series of roadmaps to 2050 on industrial decarbonisation and energy efficiency.[27] The sectors covered were those deemed to be most energy intensive, and generally align with the sub-sector groupings used in this report. However, Table 14 shows the difference in CO_2 emissions calculated for the sub-sectors in this and the DECC/DBIS reports, and indicates that the definitions of sub-sectors do not, in all cases, align very well. This will be addressed on a sector-by-sector basis below.

Table 14: Summary of DBIS's industrial decarbonisation and energy efficiency roadmaps

Industrial sub-sectors in DECC/DBIS reports	CO_2 emissions (Mt) in 2012	Corresponding industrial sub-sectors in this report	CO_2 emissions (Mt) in 2012
Iron and steel	22.8*	Iron & steel, non-ferrous metals	6.6
Chemicals	18.4	Chemicals and Rubber & plastic products	17.4
Oil refining	16.3	Coke and refined petroleum products	14.3
Food and drink	9.5	Food, drink & tobacco	9.0
Cement	7.5*	Other non-metallic mineral products	7.8
Glass	2.2*		
Ceramics	1.3		
Pulp and paper	3.3	Paper, printing, publishing	6.3

**Includes process emissions of CO_2 not related to energy consumption*
Sources: DECC/DBIS Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 and Oakdene Hollins workup of ECUK data, 2016 release, applying an energy mix based conversion factor between energy consumption and CO_2 emission.

[27] https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050

To estimate the energy efficiency savings opportunities related to the various industrial sub-sectors from the DECC/DBIS reports the business as usual (BAU) scenario was considered. BAU, in these reports, is defined as: *"decarbonisation and energy savings options that would be expected if current rates of efficiency improvement continued, and no significant intervention or outside support was provided to decarbonise the sectors by 2050"*. It excludes options that could require policy intervention or could constitute more investment than the continued roll-out of technologies that are presently being deployed across the sector as each plant or site reaches the appropriate point to implement the technology. Based on this definition we believe the BAU scenario aligns well with the no-cost/low-cost opportunities for energy efficiency savings this study is tasked with quantifying. Given that this study is focused on quick-win energy efficiency gains, only the short short-term energy efficiency savings opportunities, up to 2020, will be included. This decision was taken in order to reduce the impact of the inherent uncertainties in long term forecasts. It also produces a more realistic picture of the current status of energy efficiency opportunities in the individual sub-sectors.

Coke and refined petroleum production

In 2014, 60 million tonnes of refined petroleum and 3.6 million tonnes of coke were produced in the UK. The coke and refined petroleum production sector consumed nearly the same amount of energy in 2014, compared to 2009, according to ECUK data.[28] This is in spite of a 20% decrease in output and the closure of three refineries during this period (Teesside in 2009 (117,000 barrels per day, bpd), Coryton in 2012 (220,000 bpd) and Milford Haven in 2014 (108,000 bpd)). This steady energy consumption and decrease in output would indicate a decrease in energy intensity of 21% between 2009 and 2014. However, as discussed below, the ECUK data does not align with that compiled by the industry body the UK Petroleum Industry Association (UKPIA) which reports an increase in energy intensity of 6% over the same period.

To understand the energy consumption of this energy producing sector it is important to understand how much of the fuels produced are used on site. Refineries use a small proportion of the products they refine as fuel for their operations: UKPIA estimates that 47.3% of the fuel used in UK refineries in 2012 was refinery fuel gas, followed by petroleum coke (24.8%), natural gas (21.3%) and fuel oil (6.7%).[29] Fuel produced on site, including the refinery fuel gas, petroleum coke consumed and a proportion of the natural gas, may not be completely accounted for in the ECUK data.

Factors affecting the energy efficiency of refineries are the utilisation rate and the nature of the products they produce. Between 2009 and 2014, the utilisation rate of UK refineries has fluctuated between 75% and 88% (minimum in 2011 and maximum in 2012), mostly due to global economic factors.[30] Different refineries have higher or lower energy efficiencies because of differences in the complexity of the processes they are carrying out. If they accept heavier crude oil fractions and if they convert more heavy products to light products, they will consume more energy as a proportion of their throughput. According to a measure of refinery energy efficiency that corrects for these differences between refineries, the

28 Table 4.03 ECUK data 2016

29 Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Oil Refining, March 2015

30 UKPIA Statistical Review 2016: http://www.ukpia.com/docs/default-source/default-document-library/statistical-review-2016.pdf?sfvrsn=0

Energy Intensity Index (EII), the energy efficiency of European refineries has been steadily improving, at approximately 1% a year, since 2006.[31]

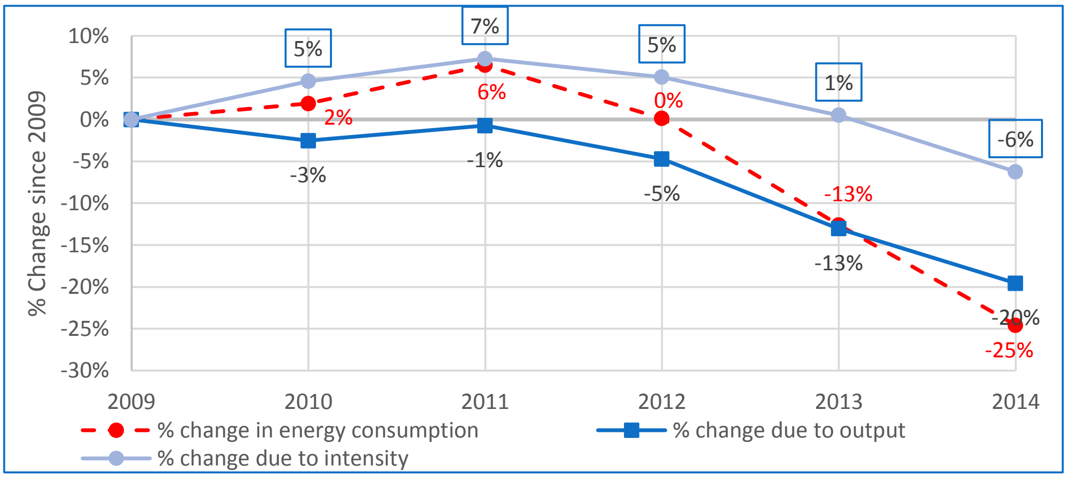
Based on the above discussion we concluded that the UKPIA energy efficiency data is more realistic than our calculations based on ECUK data (see Table 15).

Table 15: Changes in energy consumption and production index in coke and refined petroleum products sectors, 2009-14

Sub-sector	2009	2010	2011	2012	2013	2014	Source
	Energy consumption (Mtoe)						
Coke and refined petroleum products	4.3	3.8	3.7	3.7	4.5	4.2	ECUK data, Table 4.03
Refined petroleum production only	4.3	4.4	4.6	4.3	3.8	3.2	UKPIA Statistical Review 2016
	Production index (2009 = 100)						
Tonnage coke and refined petroleum products	100.0	98.1	100.3	96.0	88.1	81.5	DUKES[32] Tables 3.2-3.4
Refinery throughput	100.0	97.5	99.3	95.3	87.0	80.4	UKPIA Statistical Review 2016

Using the UKPIA data we plotted the contribution of output and intensity changes to energy consumption in the coke and refined petroleum products sub-sector in Figure 16.

Figure 16: Change in energy intensity, output in coke and refined petroleum sectors, 2009-14



Source: Oakdene Hollins workup of sector's energy consumption and output

Savings opportunities in the coke and refined petroleum products sub-sector

The CO_2 emissions figure identified in the DECC/DBIS report for the oil refining sector is relatively close to that derived in this report based on ECUK data and an energy-mix dependent toe to CO_2 conversion factor (Table 14). Coke production is not covered in the DECC/DBIS report and, as it only accounts for less than 6% of the total production tonnage of

[31] https://www.fuelseurope.eu/uploads/Modules/Resources/fuelseurope-statistical-report-2015.pdf

[32] https://www.gov.uk/government/statistics/petroleum-chapter-3-digest-of-united-kingdom-energy-statistics-dukes

the sub-sector, we will also exclude it from this derivation of no-cost/low-cost energy savings opportunities.

In calculating the contribution of no-cost/low-cost energy efficiency savings opportunities in the oil refining sector we focused on the largest opportunities which were also characterised as 'incremental'. Subtracting the decrease in emissions due to electricity grid decarbonisation and an estimated 1.04% annual decline in production, the residual emission savings in the BAU scenario were 5% in 2020 and 9% in 2050 (relative to a 2014 baseline). The no-cost/low-cost 'incremental' emissions reducing opportunities identified (see Table 16) account for about 60% of the emission savings in the BAU scenario in 2020, and 50% in 2050.[33]

Table 16: Energy savings opportunities in coke and refined petroleum products sectors

Option	Applies to	Emission saving opportunity by 2020 (% of 2014 emissions)
Advanced control and improved monitoring	All*	0.3%
Lighting	All	0.2%
Motors, pumps, compressors, fans	All	1.4%
Storage tanks	All	0.8%
Utilities optimisation	Steam**	0.4%
Total		**3.0%**

**All: applies to Total Refinery emissions*
***Steam: applies to Steam Generation Plant related emissions only*
Source: DECC/DBIS: Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Oil refining

By 2020 these no-cost/low-cost incremental changes are forecast to account for 3% of the emission reduction in the sector relative to 2014 levels. This corresponds to a financial saving opportunity of approximately £38 million (Table 17).

Table 17: Summary of estimated savings opportunities for coke and refined petroleum products sector in 2014

	% industrial energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Coke and refined petroleum products	18	4,240	3	127	495	38

The tonnes oil equivalent (toe) to tCO_2 conversion factor (3.6) and the average p/kWh (2.6) is based on the fuel mix in the sub-sector in 2014. Also, 1 toe = 11,630 kWh.
Source: Oakdene Hollins workup of sector's energy consumption and opportunities for no-cost/low-cost energy savings

Savings opportunities in the food, drink and tobacco production sub-sector

The CO_2 emissions figure identified in the DECC/DBIS report for the food and drink sector is relatively close to that derived in this report based on ECUK data and an energy-mix dependent toe to CO_2 conversion factor (see Table 14). We assume that scale of tobacco

[33] Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Oil refining

production is negligible relative to food and drink manufacture, and can be excluded from this analysis. The food and drink sub-sector is the fourth biggest, in terms of energy consumption, in the UK. Its power needs include heating and refrigeration as well as mechanical equipment on production lines. In the recent DECC/DBIS report on the food and drink sector's decarbonisation and energy efficiency, the no-cost/low-cost energy efficiency saving opportunities identified are very small at approximately 1.8% of the emissions in 2014 (Table 18).[34]

Table 18: Energy savings opportunities in food, drink and tobacco sectors

Option	Emission saving opportunity by 2020 (% of 2014 emissions)
Process design	1.0%
Steam production distribution & end use	0.4%
Other (energy management & good manufacturing practice; motors, pumps & drives, heating, ventilation, air conditioning and lighting; and compressed air)	0.4%
Total	**1.8%**

Source: DECC/DBIS: Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Food and drink

By 2050, the authors estimate that emissions from the food and drink sector could decrease by as much as 41%, though this is primarily due to grid decarbonisation and changes in sector production and not energy efficiency. BAU contributions account for 32% of this overall decrease in emissions, of which two-thirds is down to the implementation of no-cost/low-cost options.

However, in the short term (2014 to 2020), the savings opportunities presented by no-cost/low cost interventions are more modest, at less than 2%. This corresponds to a financial saving opportunity of £23 million (Table 19).

Table 19: Summary of estimated savings opportunities for food, drink and tobacco production sector in 2014

	% industrial energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Food, drink and tobacco production	12	2,840	1.8	51	163	23

The toe to tCO_2 conversion factor (3.2) and the average p/kWh (3.9) is based on the fuel mix in the sub-sector in 2014. Also, 1 toe = 11,630 kWh.
Source: Oakdene Hollins workup of sector's energy consumption and opportunities for no-cost/low-cost energy savings

Savings opportunities in the chemicals sub-sector

The CO_2 emissions identified in the DECC/DBIS report for the chemicals sector are close to those derived in this report based on ECUK data for the 'chemicals' and 'rubber and plastic product' sub-sectors combined (see Table 14). Polymer, plastic and rubber production is

[34] Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Food and Drink (March 2015)

considered to be within the scope of the chemical sector by the DECC/DBIS report. By 2050, if the BAU scenario is taken, approximately 27% fewer emissions will be produced by the chemical sector than in 2014. In spite of an expected increase in production, grid decarbonisation will reduce emissions by 36% and BAU interventions by a further 22%. In the shorter term, by 2020, the BAU emission savings identified are a more modest 3.8% of the total 2014 emissions (Table 20). These savings stem from the gradual replacement of equipment and infrastructure with more energy efficient models and a partial switch to biomass and waste derived fuels.

Table 20: Energy savings opportunities in the chemicals sector

Option	Emission saving opportunity by 2020 (% of 2014 emissions)
Biomass fuel	1.6%
Waste fuel	0.9%
Other energy efficiency savings (incl. insulation, waste heat recovery, process control, equipment and steam system efficiency)	1.3%
Total	**3.8%**

Source: DECC/DBIS: Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Chemicals

The short term, 2014-2020, no-cost/low cost opportunities identified in the chemical sub-sector corresponded to emission and energy savings of approximately 3.8%. This is equivalent to a financial saving opportunity of approximately £101 million (Table 21).

Table 21: Summary of estimated savings opportunities for chemicals sector in 2014

	% industrial energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Chemicals, Rubber & plastic products	19	4,550	3.8	173	657	99

The toe to tCO_2 conversion factor (3.8) and the average p/kWh (4.9) is based on the fuel mix in the sub-sectors in 2014. Weighting of 'chemical' and 'rubber and plastic product' sub-sectors was 66:33, based on energy consumption.
Source: Oakdene Hollins workup of sector's energy consumption and opportunities for no-cost/low-cost energy savings

Savings opportunities in the iron & steel, non-ferrous metals sub-sector

For this sector there was a large discrepancy between the CO_2 emissions calculated from the ECUK data using the energy mix dependent conversion factor (6.6 tonnes) and that reported in the DECC/DBIS report (22.8 tonnes). The main reason for the discrepancy is that the DECC/DBIS figures contain process emissions (i.e. the CO_2 that evolves during the reduction of iron oxides by coke) as well as that produced by the combustion of fuels to produce heat and energy (both direct (on-site) and indirect (electricity)). In blast furnaces, for example, these process emissions account for 65% of all CO_2 emissions.

The overall energy consumption of the sector will be based on the ECUK data only. Emissions reducing options identified in the DECC/DBIS report will only be included if they relate to reductions in energy consumption and not just process emissions. Also, as ferrous metals dominate this sector in terms of tonnage, approximately 12 million tonnes in 2014 relative to aluminium's 220,000 tonnes, non-ferrous metals have been excluded from this analysis.[35]

The major no-cost/low cost BAU options identified in the report amount to an opportunity to improve energy efficiency, and hence reduce emissions, by 2% relative to 2014 levels (Table 22). These options account for 83% of the emission reduction in the BAU scenario for 2020 and 71% in 2050.

Table 22: Energy savings opportunities in iron & steel and non ferrous metal sectors

Option	Emission saving opportunity by 2020 (% of 2014 emissions)
Steam and power production system upgrades	0.8%
Reducing yield losses	0.8%
Heat recovery & re-use - conventional options	0.1%
Other (improved automation & process control and pulverised coal injection)	0.3%
Total	**2.0%**

Source: DECC/DBIS: Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Iron & steel

The 2% short term (2014 to 2020) no-cost/low cost opportunities identified in this sub-sector equate to a financial saving opportunity of approximately £23 million (Table 23).

Table 23: Summary of estimated savings opportunities for the iron & steel and non ferrous metals sector in 2014

	% industrial energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Iron & steel, non-Fe metals	8	1,930	2	39	143	23

The toe to tCO_2 conversion factor (3.7) and the average p/kWh (5.0) is based on the fuel mix in the sub-sectors in 2014. Also, 1 toe = 11,630 kWh.
Source: Oakdene Hollins workup of sector's energy consumption and opportunities for no-cost/low-cost energy savings

Savings opportunities in the other non-metallic mineral products sub-sector

This sub-sector involves the transformation of mined or quarried non-metallic minerals, such as sand, gravel, stone, clay, and refractory materials, into products for intermediate or final consumption. These non-metallic mineral derived products include clay products (such as ceramics), glass, cement and concrete and lime and gypsum products.

To estimate the savings opportunities in this sector, the DECC/DBIS reports on cement, glass and ceramics production will be referred to. These products account for under half of the energy consumed in the sector (roughly 47%). The opportunities for no-cost/low-cost energy efficiency gains in these sectors were low, valued at less than £10 million, as detailed

[35] http://www.alfed.org.uk/files/Fact%20sheets/17-aluminium-primary-production.pdf. Though nearly three times as energy intensive as steel (14 kWh per kg for virgin aluminium vs 5 kWh per kg for cast iron) approx. 20% of aluminium production in the UK is hydro-powered.

below. Assuming cement, glass and ceramics are representative of the wider sub-sector, this would indicate that the overall saving opportunities related to the non-metallic mineral products sub-sector are as detailed in Table 24.

Table 24: Summary of estimated savings opportunities for the non-metallic mineral products sector in 2014

	% industrial energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Non-metallic mineral products	10	2,480	2	49	126	15

Based on scaling the opportunities identified for cement, glass and ceramics from 47% to 100%. The toe to tCO_2 conversion factor (3.7) and the average p/kWh (2.7) is based on the fuel mix in the sub-sectors in 2014. Source: Own workup of sector's energy consumption and opportunities for no-cost/low-cost energy savings

Summary for the industrial sector

Table 25 provides a summary of the energy savings potential in the industrial sector. This Table compiles the key findings from Section 3.3.3 as well as the savings opportunities from the paper making industry which is included in Annex C.

Table 25: Summary of estimated energy efficiency opportunities in the industrial sector, 2014

	% industrial energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	Energy consumption (ktoe)	Emissions ($ktCO_2e$)	Financial (£M)
Coke & refined petroleum products	18	4,240	3.0	127	495	38
Food, drink & tobacco production	12	2,840	1.8	51	163	23
Chemicals, Rubber & plastic products	19	4,550	3.8	173	657	99
Iron & steel, non-Fe metals	8	1,930	2.0	39	143	23
Non-metallic min prods	10	2,480	2.3	49	126	15
Paper making	6	1,510	14	211	781	53
Subtotal	**73**	**17,550**	**3.7**	**655**	**2,383**	**252**
Other	27	6,490	3.7	240	880	94
Total	**100**	**24,040**	**3.7**	**895**	**3,263**	**346**

Source: Oakdene Hollins workup of industrial sectors' energy consumption and opportunities for no-cost/low-cost energy savings

3.4 Estimate of energy savings opportunity in 2014

In summary, and as shown in Table 26, a total saving of £2,329 million could be achieved through implementing low- and no-cost energy efficiency initiatives.

Table 26: Summary of the estimated total energy savings opportunities in 2014

Sector	Estimated savings (£million)
Freight	750
Services	1,233
Industrial	346
Total	**2,329**

3.5 Review of previous studies

3.5.1 *The 2007 Defra Resource Efficiency Study*

In the 2007 Defra Resource Efficiency study[36] the savings associated with energy, using a 2006 baseline, were calculated using a six-step approach, namely:

1. Quantification of overall energy consumption in kWh. Official Department for Business, Enterprise and Regulatory Reform (BERR) Annual Business Inquiry (ABI) and Digest of UK Energy Strategy (DUKES) datasets were the primary sources of top level data. The ABI dataset provided production output by sector measured in the form of GVA or, more specifically, volume-based production in units of output per year. The DUKES dataset provided data on energy consumption in tonnes of oil equivalent (toe) which was then converted to kWh and energy intensity measured as energy use per unit of production. These two data sources used the same sector and sub-sector definitions, namely: at sector-level the 2 digit (division level) UK Standard Industrial Classification (UK SIC) and for sub-sector the 3-digit UK SIC (group level).
2. Quantification of energy savings (kWh). Heavy reliance was placed on the work undertaken by the Carbon Trust including energy efficiency benchmarking work they had undertaken in a number of sectors. This was supported by case studies and surveys undertaken by Envirowise (FastTrack initiative), ENWORKS surveys and for the transport sector the Department for Transport (DfT) Freight Best Practice Programme.
3. Conversion of physical savings (Step 2) into financial savings. This entailed using BERR data to determine the fuel mix in each sector and multiplying this with the fuel price (p/kWh) to derive a weighted average kWh price. This was then multiplied by the savings identified in Step 2.
4. Addition of any hidden cost savings. The Climate Change Levy (CCL) was considered the most significant hidden saving; the CCL being a tax on non-domestic use of energy, introduced in April 2001.
5. Grossing up. It was not possible to cover all sectors or sub-sectors in Steps 1 to 4, and hence a grossing-up stage was required. This involved applying the estimated mean savings (%) as a weighted average.
6. Regional analysis. The analysis involved splitting up the projected UK-level savings, derived in Steps 1 to 5, by government region.

[36] Defra 2007, Quantification of the business benefits of resource efficiency. October 2007.

Table 27 provides a summary of the no-cost/low-cost energy savings opportunities. Please note that the listed sub-sectors do not follow the UK SIC convention. This is the classification system used by the Carbon Trust from which many of the savings opportunities were derived in Step 2. Table 27 shows the savings to be dominated by road freight; accounting for £2,017 million of the total £3,349 million saving, equating to 60% of the total energy savings. The Freight Best Practice Programme, the Climate Change Agreement (CCA) targeting the energy intensive industries and the benchmarking work undertaken by the Carbon Trust were considered the best means of realising these savings.

Table 27: Summary of the no-cost/low-cost energy savings opportunities identified in the 2007 report

Sector	Sub-sector	Estimated savings (%)	Estimated savings (excluding CCL) (£M)	Estimated total savings (including CCL) (£M)
Industrial	Chemicals	7.0	176	189
	Coke, refined petroleum products & nuclear fuel	2.0	60	64
	Basic metals / Mechanical engineering	4.4	77	83
	Food & drink	5.5	72	77
	Paper, printing & publishing	4.5	49	53
	Vehicles	4.0	27	29
	Textiles	7.1	25	27
	Electrical engineering	6.2	25	27
	Construction	12.4	27	28
	Other	4.8	103	110
Commercial (Service)	Retail	11.3	130	141
	Hotels	13.0	101	109
	Warehouses	10.0	71	77
	Commercial offices	17.4	93	101
	Education	10.0	48	52
	Government	15.0	46	50
	Sports & leisure	7.4	24	26
	Health	6.7	16	17
	Other	11.0	17	18
Transport	Road freight	11.0	2,017	2,017
Agriculture	All	20.0	53	54
	Total		**3,257**	**3,349**

3.5.2 *The 2011 Defra Resource Efficiency Study*

The methodology used in the 2011 study[37] differed significantly from that of the 2007 study. Instead of building the estimates up from scratch, an activity based approach was used, i.e. investigating the change in resource efficiency in each business sector since the 2006 baseline (determined in the 2007 study).

The general approach used within this study is:

- Step 1: Quantify overall energy consumption by UK economic sector in 2009. This was a replication of the approach used in Step 1 of the 2007 study.
- Step 2: Determine the causative factors for any changes in consumption or generation since 2006, i.e. is the change in consumption/generation between 2006 and 2009 due to changes in sector output or intensity based changes (improved efficiencies)? The initial approach was to use the DECC annual energy consumption data tables for the UK[38] combined with monetary output data from the ONS' Blue Book[39]. However this approach gave volatile results due to Service sector reclassifications[40] and possible distortions introduced by using monetary output as a proxy for underlying activity in the Industrial sector. An alternative approach was developed based on a study by the Carbon Trust[41] which identified the savings opportunities for the services, retail, public and chemicals sectors in 2009 and for the other high energy intensive industrial sectors the data from the sector-level CCA was used. *Please note: typically only the larger companies within each sector are party to the CCA, and since companies outside of CCAs are likely to have lower reductions in energy intensity, this was factored into the calculation.*
- Step 3: Quantify the no-cost/low-cost intensity based interventions (payback less than one year) realised between 2006 and 2009.
- Step 4: Determine the 2009 no-cost/low-cost resource efficiency opportunity using the information gathered in Steps 1 to 3.

Table 28 provides a summary of the top 10 sub-sectors, in terms of energy savings opportunities, identified in the 2011 study and compares this against the 2006 estimates. The analysis appears to show that the savings opportunity increased between the two studies but this is due to the 'mainly own account – HGV and LGV' which was inadvertently omitted from the original 2006 study. When this is removed to enable a like-for-like comparison, it shows that the estimated savings opportunity reduced from £3,349 million to £2,770 million; a reduction of £579 million or 17%. It can also be seen that in 2009 the general category 'road freight' represented the top three opportunities and in total accounted for 72% of the estimated financial savings (£2,763 million of the £3,820 million). A full list of the energy savings identified in the 2011 study is shown in Annex A.

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37 Defra 2011, The further benefits of business resource efficiency. March 2011.

38 DECC (2010), *Energy Consumption in the UK, Industrial (Service; Transport) Data Tables: 2010 update*

39 ONS (2010), *The Blue Book – UK National Accounts: 2010 edition*

40 DECC, personal communication

41 Carbon Trust (2010), *Breaking through the barriers: Unleashing energy efficiency in the UK*.

Table 28: Summary of no-cost/low-cost energy efficiency savings opportunity for 2006 and 2009

<table>
<tr><th rowspan="2">Sub-sector</th><th colspan="2">Savings opportunity (£M)</th><th rowspan="2">Change in opportunity 2006 to 2009 (£M)</th></tr>
<tr><th>2006</th><th>2009</th></tr>
<tr><td>Mainly own account – HGV and LGV</td><td>NA</td><td>1,050</td><td>NA</td></tr>
<tr><td>HGV – mainly public haulage</td><td rowspan="2">2,017</td><td>1,027</td><td rowspan="2">-304</td></tr>
<tr><td>LGV – mainly public haulage</td><td>686</td></tr>
<tr><td>Retail</td><td>141</td><td>140</td><td>-1</td></tr>
<tr><td>Chemicals, chemical products, man-made fibres</td><td>189</td><td>90</td><td>-99</td></tr>
<tr><td>Hotels</td><td>109</td><td>99</td><td>-10</td></tr>
<tr><td>Commercial offices</td><td>101</td><td>101</td><td>0</td></tr>
<tr><td>Warehouses</td><td>77</td><td>79</td><td>2</td></tr>
<tr><td>Education</td><td>52</td><td>71</td><td>+19</td></tr>
<tr><td>Government</td><td>50</td><td>72</td><td>+22</td></tr>
<tr><td>Subtotal</td><td>2,736</td><td>3,415</td><td>+679</td></tr>
<tr><td>TOTAL</td><td>3,349</td><td>3,820</td><td>+471</td></tr>
</table>

4 Waste

4.1 Quantification of waste savings in 2014

Based on 2014 UK waste data, waste saving opportunities of between £3,072 million and £4,612 million have been estimated to be achievable as a result of no-cost/low-cost actions.

The sections below outline the methodology used, and supporting evidence drawn on, to arrive at these savings estimates. In addition there is a summary of the findings of the two previous reports based on 2006 and 2009 data.

4.2 Methodology

The methodology used to estimate the value of waste savings at an economy-wide level are based on two key sources of information:

- Snapshot studies looking at waste minimisation in specific sectors.
- Estimates based on economic output trends and sector level waste generation data.

Snapshot studies frequently provide the best source of information, generally providing more accurate and reliable data as they are based on case studies and real data or real estimates, frequently drawing on direct industry input. However these studies do not always exist for all sectors, or cover the right time frames. By contrast, sector-wide estimates relying on modelling techniques have to make assumptions and can only ever therefore offer estimates that must be understood within this context. One such example is the assumption that there is a linear relationship between waste production and economic output such that a 10% increase in output would be mirrored by a 10% increase in waste generation. Using this assumption, savings arising from waste prevention measures can be separated from waste changes resulting from output changes. It may be the case that the trajectory of waste generation levels is concave, not linear, but without clarity around such relationships a simple linear relationship has been assumed.

In addition the changes in the calculation methods and data quality relating to waste data over time need to be considered. This is of particular relevance when looking back at the previous business resource efficiency studies and the estimates made in these studies.

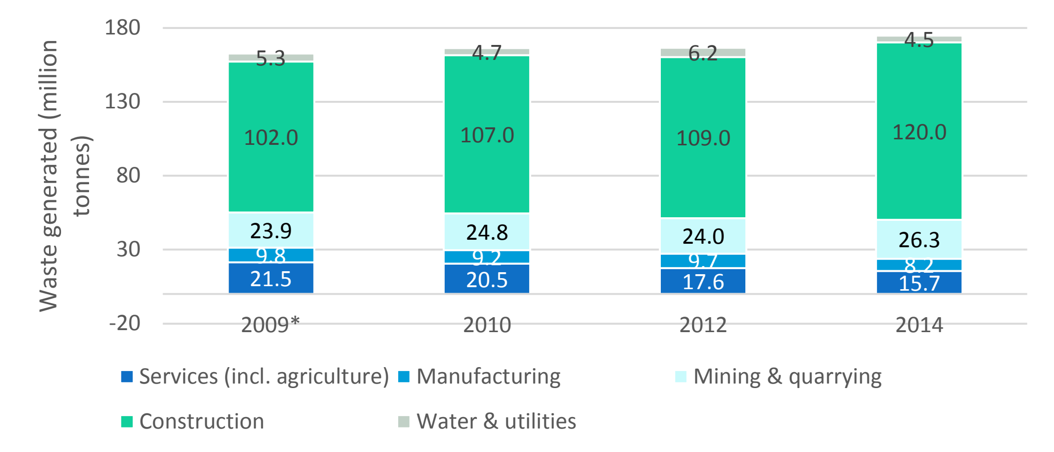
A combination of information from both case studies and modelling have been used to assess the savings possible for the 2014 waste data baseline. The following steps were taken:

1. Analysis of the Defra waste statistics to determine the trends in waste generation between 2009 and 2014. 2009 was chosen as a starting point because this was the base year of the previous (2011) study.
2. Determination of the causative factors for any changes in waste generation in the sectors generating the highest levels of waste (determined in Step 1). As with the energy sector methodology, it was necessary to interpret the findings with a high level of caution due to the need to use monetary output measures (GVA) which do not necessarily link with physical production output.
3. Undertaking a literature review to identify any supporting evidence. Part of this review included an assessment of the practical / aspirational nature of the evidence.
4. Quantification of savings opportunities.

4.3 UK waste generation – trends since 2009

Defra produces UK total waste generation statistics every two years with the latest release[42] being for 2014. In addition, heavily revised statistics have recently been produced for 2010 and 2012. Figure 17 provides a summary of the overall waste generated in each of these three years by sector. Further, results for 2009 have been derived by projecting back the trend shown in the series to 2009. The analysis shows that between 2010 and 2014 the overall quantity of waste generated increased from 166.2 million tonnes to 174.7 million tonnes; an increase of 8.5 million tonnes or 5.1%. Projecting this trend back to 2009, the waste generated in 2009 would be 162.5 million tonnes. These figures show a 12.2 million tonne increase in waste arisings between in 2014 compared to 2009, a 7.5% increase.

Figure 17: Waste generation for services and industrial sectors 2009, 2010, 2012 and 2014



**2009 values were produced by casting the Defra data from 2010, 2012 and 2014 back to 2009.[43]*
Source: Defra. UK statistics on waste data – December 2016 update

Table 29 shows the change in waste generation between 2009 and 2014 by sector and this shows that the trends vary considerably with construction and mining & quarrying increasing significantly and the other three sectors showing a substantial reduction. The sheer size of the construction sector in terms of the waste generated results in this sector having a major influence on the overall waste generation trends.

Table 29: Change in waste generation between 2009 and 2014 by sector

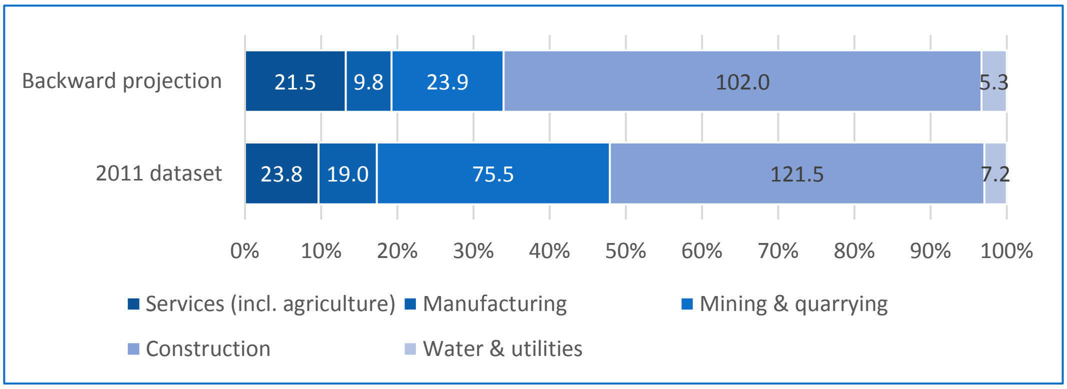
Sector	Waste generation (million tonnes)			% change
	2009 estimate	2014 estimate	Change 2009 to 2014	
Services	21.5	15.7	-5.8	-27.0
Manufacturing	9.8	8.2	-1.6	-16.3
Mining & quarrying	23.9	26.3	+2.4	+10.0
Construction	102.0	120.0	+18.0	+17.6
Water & utilities	5.3	4.5	-0.8	-15.1

[42] Defra. UK statistics on waste data – December 2016 update.
[43] Straight line fit of 2010, 2012 and 2014 data used in projection.

Source: Defra. UK statistics on waste data – December 2016 update

The aforementioned revisions made to the 2010 and 2012 waste datasets by Defra cause significant discrepancy between this and the previous study. For example, in the 2011 dataset it was estimated that 247 million tonnes of waste were generated in 2009, whereas the back projection shown in Figure 17 shows 162.5 million tonnes. The majority (60%) of the difference between the two datasets is due to the difference in the waste arisings attributed to the mining and quarrying sector (see Figure 18). This could be due to on-site backfilling not being included in the waste statistics compiled by Defra. The Defra estimates do not align with the British Geological Survey (BGS) estimates. The BGS estimate that the total mineral waste produced in the UK, in 2014, was 84.3 million tonnes, or approximately three times that recorded in Defra's waste statistics (26.3 million tonnes shown in Figure 17).[44] The most likely cause of this discrepancy is the method of accounting for 'unused material extraction' or 'backfilling', e.g. in open cast mining where spoil is reused on-site for land restoration. Given the significance of the discrepancy between the two estimates, it is recommended that the criteria used by Defra and the BGS be reviewed to determine the causes of this misalignment.

Figure 18: Comparison of the 2011 and 2016 datasets for waste generation in 2009



Source: Defra. UK statistics on waste data – December 2016 update (of 2010, 2012 and 2014 data on which backward-projection was based) and the 2011 release of UK statistics on waste data used in the previous study

4.4 Sector level analysis of resource efficiency opportunities

This section explores at the sector-level whether these trends can be attributed to a change in resource efficiency (intensity) or result from a change in economic output, and provides the estimates for opportunities of financial savings from no-cost/low-cost initatives.

4.4.1 *Services sector*

The volume of waste arisings attributed to the UK services sector has decreased by nearly 30% between 2009 and 2014 (shown in Figure 17 and Figure 19).[45] At the same time there was an 11% increase in economic output. It can therefore be assumed that the change is predominantly due to waste prevention efforts. However, to achieve such a dramatic reduction in waste generation in a sector showing significant economic growth would

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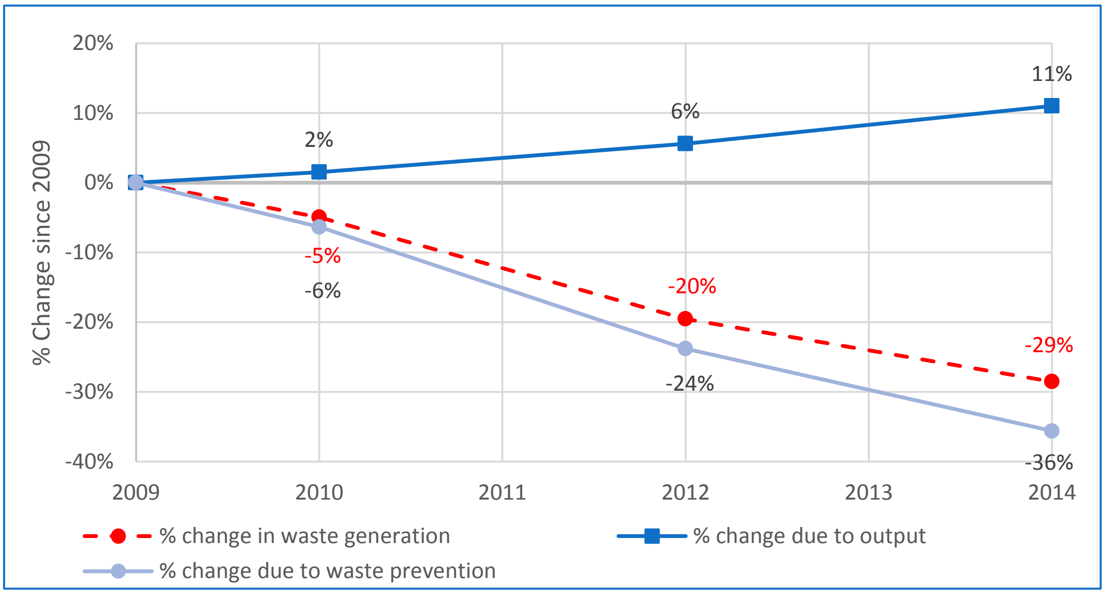
[44] Mineral waste in the UK: Innovation, optimisation and recycling. Clive Mitchell, BGS.

[45] Please note: the difference between 27% shown in Figure 17 and 29% shown in Figure 19 is due to rounding error.

require an efficiency improvement of 36% (Figure 19). This substantial improvement would suggest that the no-cost/low-cost savings opportunities are likely to have been realised across the service sector and this assumption is analysed below.

Figure 19: Change in output and waste generation (%) in the services sector 2009-14



Source: Oakdene Hollins workup of Defra's UK statistics on waste data – December 2016 update, using GVA, as reported by the ONS, as a measure of sub-sector output.
Note: Factors other than waste prevention could contribute to the change in waste generation reported for a sector, such as: changes in data methodology and changes in the composition of waste generated

Unfortunately, the Defra waste survey does not split the service sector into sub-sectors. However, a study undertaken by Natural Resources Wales (NRW)[46] in 2012 showed that in Wales the two most prominent sub-sectors in terms of waste generation were:

- The wholesale and retail sub-sector, accounting for 52% of all service sector waste (859,420 tonnes in 2012).
- The accommodation and foodservice sector, accounting for 15% of service sector waste (244,692 tonnes in 2012).

These two sub-sectors are investigated in more detail to identify further opportunities for waste reductions.

Wholesale and retail sector

Food waste represents one of the biggest opportunities in the wholesale and retail sector. A study by WRAP[47] estimated that 0.227 million tonnes (0.21 million tonnes in retail and 0.017 million tonnes in wholesale) of preventable (avoidable) food waste was generated in the sector in 2014 at a cost of £0.3 billion. It is estimated by WRAP that 10% of the waste generated could be avoided through low cost practical measures, which equates to 22,700 tonnes and a cost saving of £30 million.

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[46] Natural Resources Wales: Survey of industrial and commercial waste generated in Wales in 2012.
[47] WRAP 2015, Estimates of food and packaging waste in the UK grocery retail and hospitality supply chains.

Packaging waste was cited as the key opportunity in the previous studies with a particular emphasis on using more returnable (reusable) packaging in place of corrugated cardboard. The WRAP study estimated that 1.2 million tonnes of packaging waste were generated in the wholesale (0.132 million tonnes) and retail (1.068 million tonnes) sectors at a cost of £1.9 billion.

Unfortunately, it is not possible to determine a detailed composition of the retail waste through the Defra waste data since it includes a very large amount of mixed waste classified as 'household or similar'. The NRW 2012 report found that paper and cardboard was the most dominant waste stream in the commercial sector accounting for 537 thousand tonnes or 62.5% of the total commercial waste in Wales. This was broken down thus:

- An estimated 426 thousand tonnes of cardboard (79%).
- Approximately 40 thousand tonnes of paper (7%).
- Around 71 thousand tonnes of mixed paper & cardboard (13%).

Most of the paper and cardboard waste generated by the commercial sector was reckoned to be packaging waste (91%). The wholesale and retail sector generated 380 thousand tonnes or 71% of all commercial paper and cardboard waste.

Cardboard and paper is the most highly recovered or recycled packaging material in the UK, as shown in Table 30. With a recovery rate of 89.4% in 2013 there is very little scope to increase the recovery rate. WRAP has undertaken numerous case studies highlighting the resource efficiency opportunities associated with the optimisation of cardboard packaging with many reporting weight savings in excess of 30%[48] or more through the use of reusable packaging. However, the shift from single-use to reusable packaging cannot be considered a no-cost/low-cost option due to the investment required in the purchase of the reusable packaging and the change in the logistics associated with the recirculation of the reusable packaging. For this study, a more conservative 3% reduction is considered appropriate and this is associated with the lightweighting opportunity for single use packaging. This is in line with the WRAP Courtauld Commitment 3 targets (2012 to 2015) and is mindful of the fact that reductions in the weight of the packaging could have a detrimental impact on its functionality and could cause more product failures and damage. Using the WRAP data above, showing that an estimated 1.2 million tonnes of packaging waste was generated at a cost of £1.9 billion, a 3% saving equates to 36,000 tonnes or £57 million.

Table 30: Total packaging waste and waste recycled in the UK in 2013

Sector	Waste arising	Recovered or recycled	% recovered or recycled
Aluminium	164	71	43.3
Steel	642	391	60.9
Paper	3,868	3,459	89.4
Glass	2,399	1,639	68.3
Plastic	2,260	714	31.6
Wood	1,029	436	42.4

Source: Statista. Amount of packaging waste and waste recycling in the UK for 2013

[48] WRAP (date unknown), Cardboard packaging optimisation: best practice techniques.

In summary, the savings opportunity in the wholesale and retail sector is a £30 million saving in food waste and a £57 million saving in packaging, equating to an overall saving of £87 million or 58,700 tonnes.

Hospitality and foodservice (HaFS) sector

The HaFS sector did not present significant savings opportunities in the previous 2011 study. However, in 2013 WRAP undertook a study[49] to quantify the true cost of food waste in the UK's HaFS sector and valued the cost of the 683,600 tonnes of avoidable food waste generated at £2.5 billion (Table 31). The WRAP report suggests that the quick-win represents a £250 million saving equating to a reduction in avoidable food waste of 68,360 tonnes.

Table 31: The cost of avoidable food waste in the nine sub-sectors of the HaFS

Sector	Total wastage (tonnes)	Avoidable waste (tonnes)	Cost of avoidable food waste (£/tonne)	Cost of avoidable food waste (£M)
Restaurants	199,100	142,600	4,775	680.9
Quick service restaurants	76,400	59,200	4,506	266.8
Pubs	173,300	123,600	2,896	357.9
Hotels	78,700	49,400	6,332	312.8
Leisure	59,900	41,000	5,833	239.2
Staff catering	20,900	15,300	2,980	45.6
Healthcare	120,700	96,700	2,384	230.5
Education	122,600	99,400	2,535	252.0
Services	67,700	56,300	1,971	111.0
Total	**919,300**	**683,600**	**3,700**	**2,500**

Source: WRAP. The true cost of food waste within hospitality and food service, November 2013

Taking the NRW analysis that the two sectors account for 67% of the total services waste estimate, grossing-up the savings in these two sub-sectors to the whole of the service sector provides an overall estimate of £503 million for 2014 (Table 32).

Table 32: Summary of estimated savings opportunities in the services sector in 2014

Sector	Estimated savings (£million)
Wholesale and retail	87
Hospitality and foodservice	250
Subtotal	337
Other	166
Total	**503**

Source: Oakdene Hollins workup of Defra's UK statistics on waste data – December 2016 update
Other includes public sector services, care homes, administrative services, schools and hospitals.

49 WRAP 2013, the true cost of food waste within hospitality and food service, November 2013.

4.4.2 *Manufacturing*

According to the Defra 2014 statistics, the three biggest manufacturing sectors in terms of waste generation are:

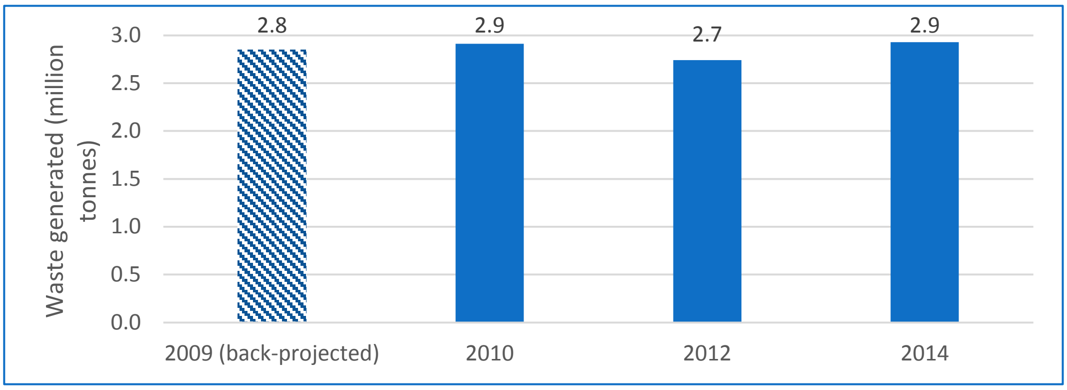
- Manufacture of food products, beverages and tobacco products (2.9 million tonnes).
- Manufacture of chemical, pharmaceutical, rubber and plastic products (1.8 million tonnes).
- Manufacture of basic metals and fabricated metal products, except machinery and equipment (1.6 million tonnes).

Generating 6.3 million tonnes of waste per year combined, these three sectors account for over three-quarters of all the waste generated by manufacturing in the UK and, as such, are the focus of the detailed analysis below.

The food and drink sector

Figure 20 shows the trend in waste generation over the period 2009 to 2014. This shows that waste arisings have fluctuated between 2.7 and 2.9 million tonnes with no clear upward or downward trends.

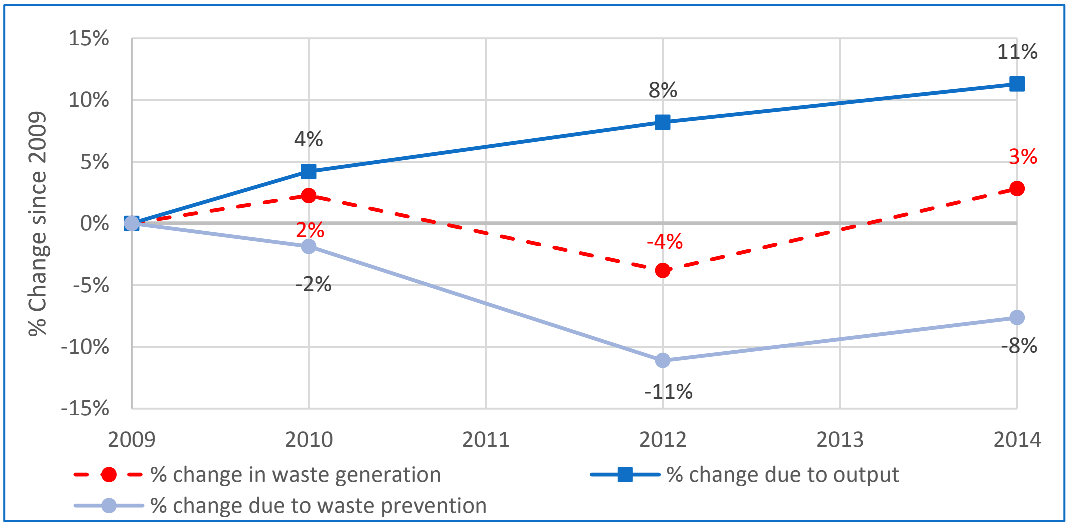
Figure 20: Trends in waste generation in the food, drink and tobacco sector



Source: Defra. UK statistics on waste data – December 2016 update

Figure 21 shows that although waste generation fluctuates over the period 2009 to 2014, the output (measured in sector GVA) increased by 11% and showed a year on year upward trend. In terms of waste prevention or intensity the chart shows that less waste was generated per unit of economic output (GVA) indicating steady improvements amounting to an 8% reduction of waste per unit of economic output. The net change in total waste generation between 2009 and 2014 is a small increase of 3%.

Figure 21: Change in waste generation, intensity and output in the food and drink sector



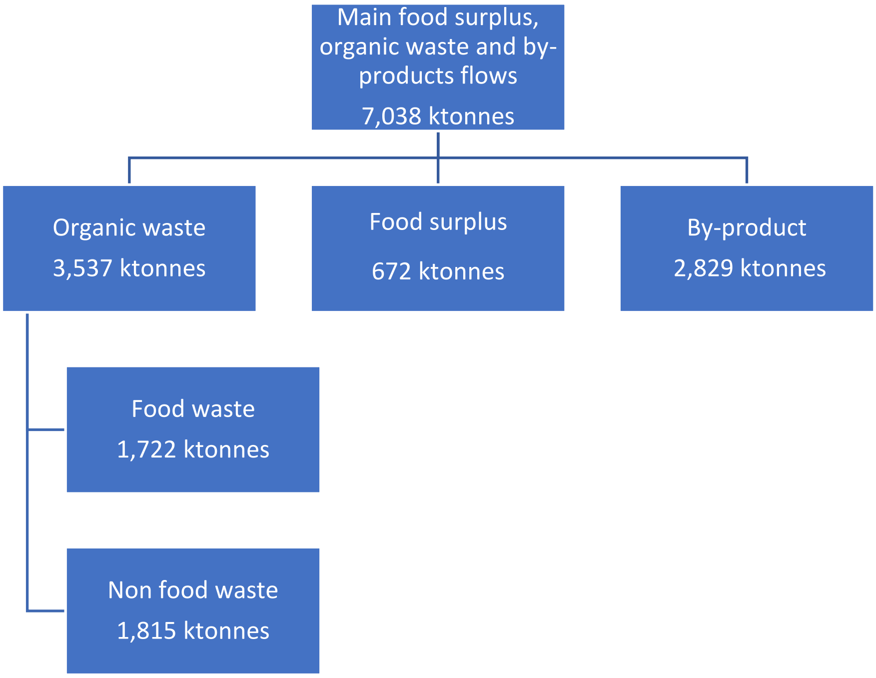
Source: Oakdene Hollins workup of Defra's UK statistics on waste data – December 2016 update, using a measure of sub-sector output listed in Table 57.

Waste prevention is at the top of the waste hierarchy as it reduces material consumption and negates the need for waste treatment. The WRAP Courtauld Commitment (phases 2 and 3) ran between 2009 and 2014 and resulted in a 10.6% reduction in waste generated in the supply chain of signatories, both retailers and manufacturers. In addition, the obligations of the WRAP Courtauld Commitments have impacted on the waste generated by non-signatories, and it is reported that between 2009 and 2012 a 7.4% reduction occurred in the supply chain of signatories and a 6% reduction in non-signatories.[50]

Since the 2011 *Business Resource Efficiency* report much work has been focused on the organic material flows in the food and drink sector with a particular emphasis on food waste from an ethical, economic and environmental perspective. Figure 22 provides the summary of the material flows in 2014. Changes in definitions have taken place since the previous study with the emergence of the non-waste term 'food surplus' for organic material being redistributed for human consumption or being used as animal feed. By-products are outputs of the food and drink production process that are neither the primary product or a waste: they are outputs destined for secondary markets such as animal feed, other food production processes (e.g. whey from cheese production used in nutritional supplements) or non-food applications.

[50] WRAP 2016, Quantification of food surplus, waste and related materials in the grocery supply chain. May 2016.

Figure 22: Organic material flows in the UK food and drink manufacturing sector in 2014



The WRAP 2016 report estimates that of the 1,722 thousand tonnes of food waste generated in 2014, 355,000 tonnes is practically avoidable and 870,000 tonnes theoretically avoidable. For this study the 355,000 tonnes that are practically avoidable are considered the no-cost/low-cost opportunity and the study breaks the tonnage down thus:

- 155,000 tonnes can be prevented at source.
- 70,000 tonnes can be redistributed.
- 130,000 tonnes can be diverted to animal feed.

The WRAP 2016 report includes the following examples of the no-cost/low-cost prevention interventions:

- Avoidance of spoilage through improved temperature control.
- Better stock control procedures, such as ‘first in, first out’ (FIFO).
- Better waste measurement and feedback.
- Improvements to forecasting and processes around changes to orders.

From a financial cost saving perspective, the 155,000 tonnes prevented at source represents the most significant opportunity to the manufacturers. Table 33 provides a breakdown of the reported savings by sub-sector. Using the derived monetary value in the WRAP 2016 report of £1,189 per tonne, the savings opportunity equates to £184 million. Assuming the remaining 200,000 tonnes are diverted from local anaerobic digestion (AD) facilities with a gate fee of £40 per tonne[51] and the redistribution and animal feed options would be cost neutral, the savings opportunity is valued at £8 million. The total savings opportunity is therefore £192 million.

[51] WRAP Gate Fees Report 2014

Table 33: Potential to prevent food waste arising, by manufacturing sub-sector, ranked by tonnage

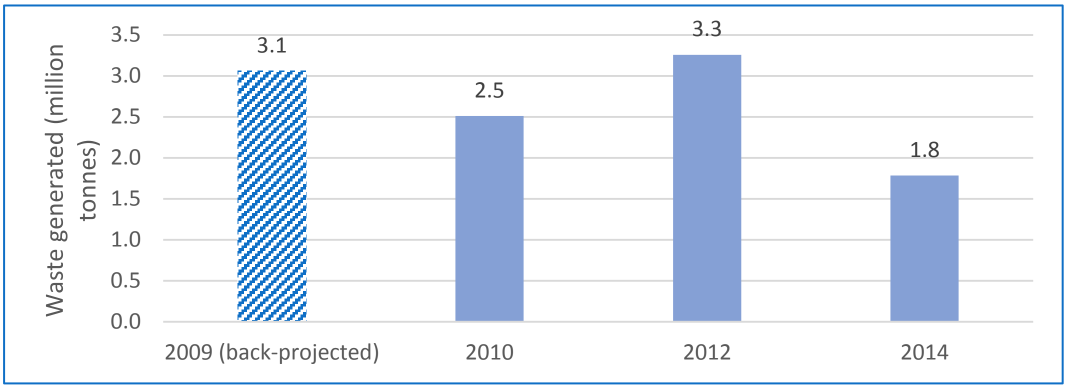
Sub-sector	Potential to prevent food waste arising (tonnes)
Dairy products	40,000
Ambient products	30,000
Meat, poultry and fish	20,000
Fresh fruit and vegetable processing	17,000
Pre-prepared meals	15,000
Bakery, cake and cereals	10,000
Alcoholic drinks	8,000
Soft drinks and fruit juices	5,000
Confectionery	4,500
Milling	500
Sugar	100
UK total	**155,000**

Source: WRAP 2016, Quantification of food surplus, waste and related materials in the grocery supply chain. May 2016

The chemicals sector

Figure 23 shows the trend in waste generated in the chemicals sector reported by Defra. This shows a significant fluctuation in arisings including a 1.5 million tonne reduction between 2012 and 2014.

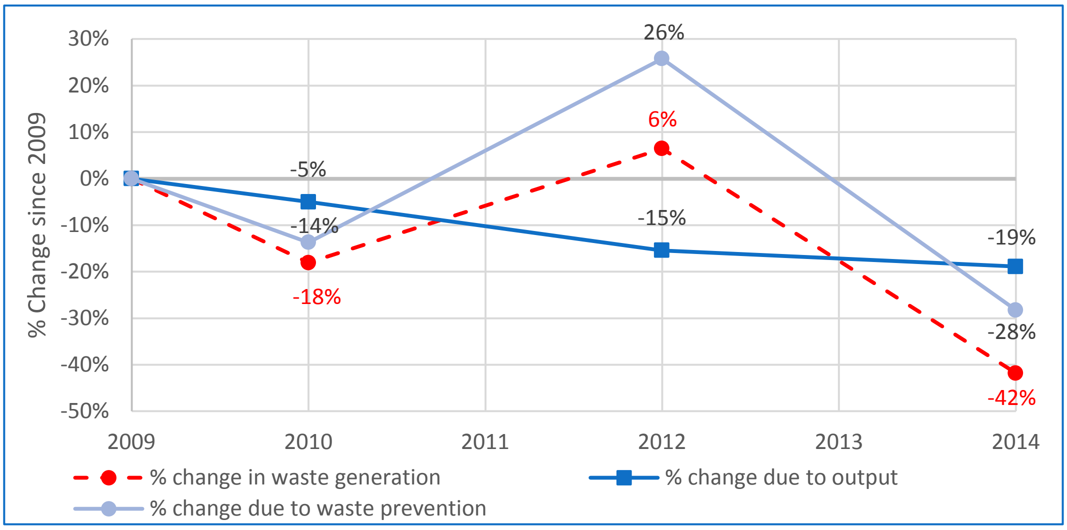
Figure 23: Trends in waste generation in the chemicals, pharma, rubber and plastics sector



Source: Defra. UK statistics on waste data – December 2016 update

The 1.5 million tonnes reduction in waste generation between 2012 and 2014 is unexplained when compared against the economic output of the sector. Figure 24 shows that the economic output from the chemical sector has reduced year-on-year with a 19% reduction from 2009 to 2014 and, more specifically, from -15% to -19% from the 2009 base year between 2012 and 2014, i.e. a 4 percentage points reduction. Since the calculation of the intensity is dependent on the relationship between waste generation and output, Figure 24 naturally shows the intensity over the 2009 to 2014 timeframe to be equally as volatile, i.e. it moves from a +26% increase in intensity in 2012 to -28% in 2014. As such, the apparent net waste prevention improvement from 2009 to 2014 (28% reduction) indicated in Figure 24 cannot be attributed to a sustainable improvement in waste prevention and provides evidence of the frailty of this approach to determining the realised savings. The review of the remaining savings opportunities will therefore be solely based on the review of literature that follows.

Figure 24: Change in waste generation in the chemical, pharma and rubber sector



Source: Oakdene Hollins workup of Defra's UK statistics on waste data – December 2016 update, using a measure of sub-sector output listed in Table 57.

European-wide policy initiatives are already addressing the challenges in energy efficiency in this sub-sector. The Horizon 2020 project entitled 'Sustainable process industry[52] through resource and energy efficiency' (SPIRE) is a public-private partnership (PPP) with European Union funding of EUR 900 million over the seven year period 2014 to 2020. As part of the initiative a roadmap was developed in 2012 whereby a target of a 5-10% reduction in primary resources feedstock intensity was set for the early phase of the work up to 2020. The types of intervention included were:

- Enhancing the availability and quality of existing resources.
- Optimal valorisation of industrial waste and recycled end-of-life materials as feed.
- Advancing the role of sustainable biomass / renewables as industrial raw material.

These interventions are considered a mix of quick-wins, technical interventions and longer-term investments, but unfortunately no such categorisation is made within the SPIRE roadmap. It is therefore assumed that there is an equal split between the two, and the raw materials savings opportunity from no-cost/low-cost interventions range between 2.5% and 5%. Using the estimate from the 2011 study that a 15% raw material saving equates to £3.5 billion (Table 40) the 2.5% to 5% saving falls between £583 million and £1.166 billion.[53]

The SPIRE report states that the following skills and activities are required to support resource efficiency within the process industry:

- Strategic business management to build resource-efficient business models leading to bottom line benefits and in preparation for new regulations.
- Business / financial accounting services around carbon and natural environment accounting.

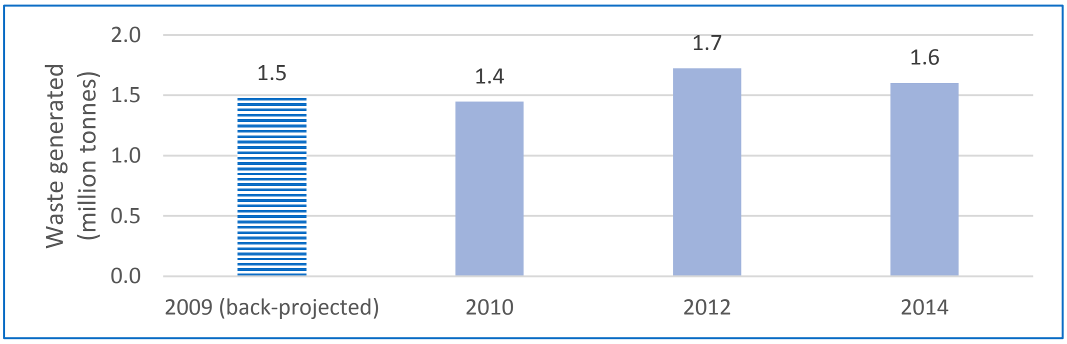
[52] The process industry is made up of eight sectors: chemicals, cement, ceramics, minerals, steel, non-ferrous metals, industrial water and process engineering.
[53] Defra 2011. The further benefits of business resource efficiency. Oakdene Hollins, March 2011.

- Skills to design and adopt technologies, products and processes increasing resource efficiency, including 'lean' manufacturing.
- Project management skills with clear understanding of resource efficiency.
- Operator level actions to maximise resource efficiency (e.g. reducing waste in production).

The basic and fabricated metals sector

Figure 25 shows no distinct trend in waste arisings between 2009 and 2014.

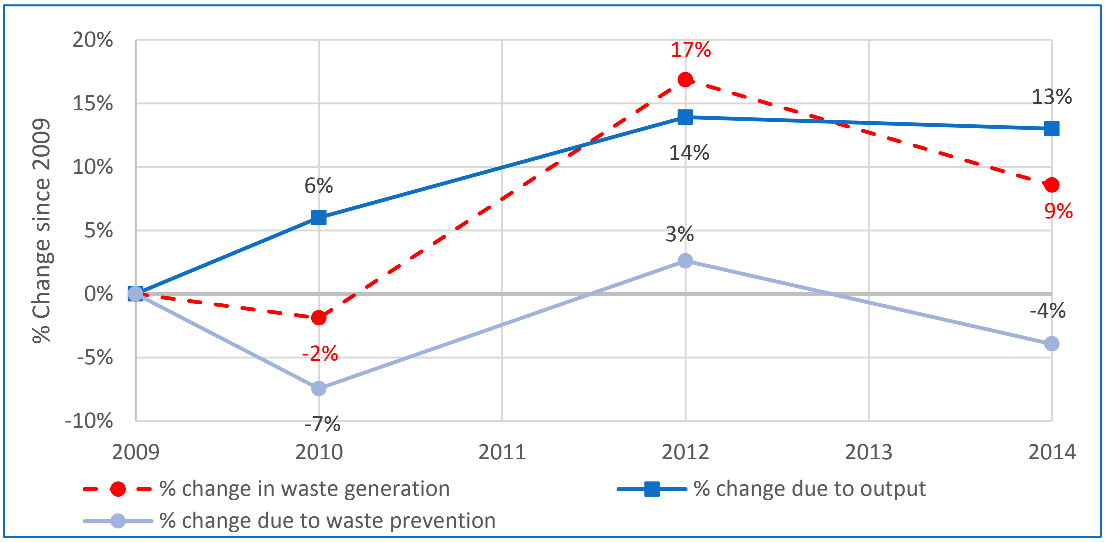
Figure 25: Trends in waste generation in the basic & fabricated metals sector



Source: Defra. UK statistics on waste data – December 2016 update

Figure 26 shows that waste arisings in the sector have increased by 9% in the period 2009 to 2014. With the economic output of the sector increasing by 13%, waste prevention measures have done little to counteract this trend, supporting only a 4% reduction. The fluctuating nature of the percentage change due to waste prevention over the time period reduces the confidence that real sustainable changes have been made.

Figure 26: Change in waste generation in the basic and fabricated metal sector



Source: Oakdene Hollins workup of Defra's UK statistics on waste data – December 2016 update, using a measure of sub-sector output listed in Table 57.

The basic and fabricated metal sector, like the chemicals sector, is included in the cluster of sectors classified as 'process industry'. Therefore the findings of the SPIRE roadmap can again be applied in a similar way to that used to provide the valuation of saving potential within the chemicals sector.

Using the estimate from the 2011 study that a 15% raw material saving equates to £2.329 billion (Table 40) the 2.5% to 5% saving falls between £388 million and £776 million.[54]

The manufacturing sector as a whole

Grossing-up the savings in these three sub-sectors to the whole of the manufacturing sector gives an overall estimate of savings of between £1,743 million and £3,283 million (Table 34).

Table 34: Summary of savings opportunities in the manufacturing sector

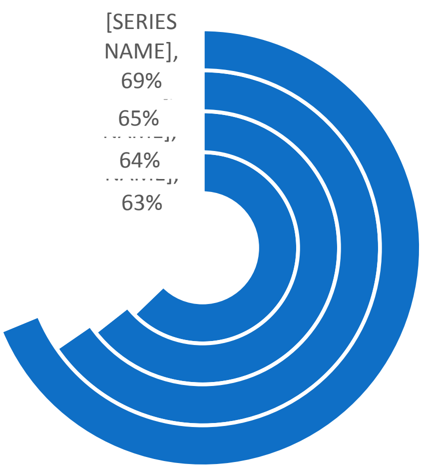
Sector	Estimated savings (£million)
Food and drink	192
Chemicals	583 to 1,166
Basic metals	388 to 776
Subtotal	1,133 to 2,134
Other	610 to 1,149
Total	**1,743 to 3,283**

Source: Oakdene Hollins workup of Defra's UK statistics on waste data – December 2016 update for each industrial sub-sector.

4.4.3 The construction sector

The construction sector is by far the largest source of waste arisings in the UK economy. Since 2009 its share of total non-household waste arisings have increased from 63% to 69% (Figure 27).

Figure 27: Construction waste as a % of total industrial and commercial waste arisings



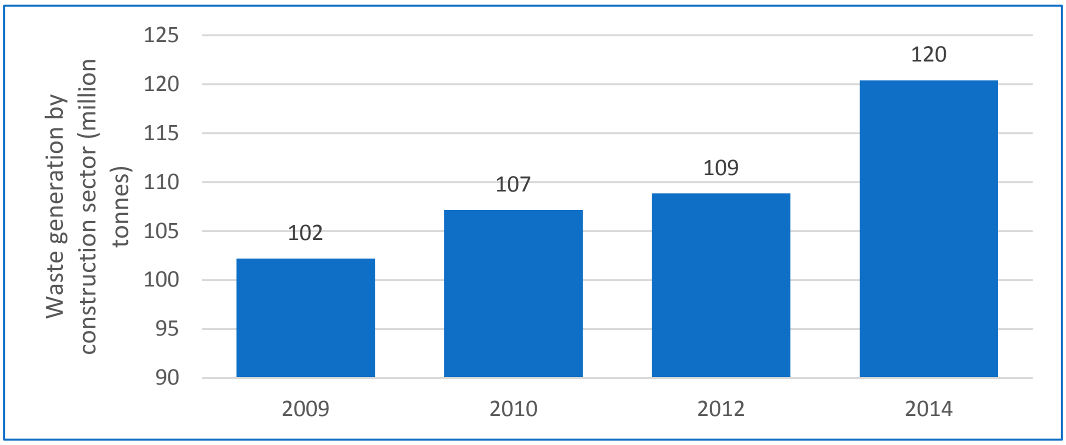
Source: Defra. UK statistics on waste data – December 2016 update

The growth in construction sector waste depicted in Figure 28 can mainly be attributed to the recovery of the sector since the 2008-09 recession. Construction output, in terms of GVA, increased 13% between 2009 and 2015. However, as is evident in Figure 29, there has

[54] Defra 2011. The further benefits of business resource efficiency. Oakdene Hollins, March 2011.

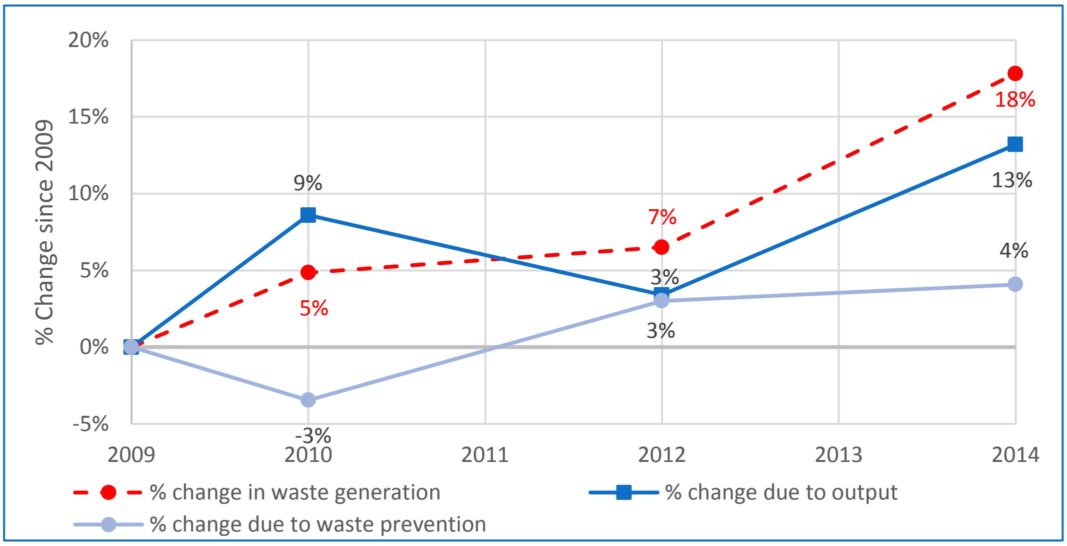
also been a slight reduction in the effectiveness of the waste prevention measures being applied in the construction sector (4% increase).

Figure 28: Waste generation in the construction sector



Source: Defra. UK statistics on waste data – December 2016 update

Figure 29: Change in waste generation in the construction sector



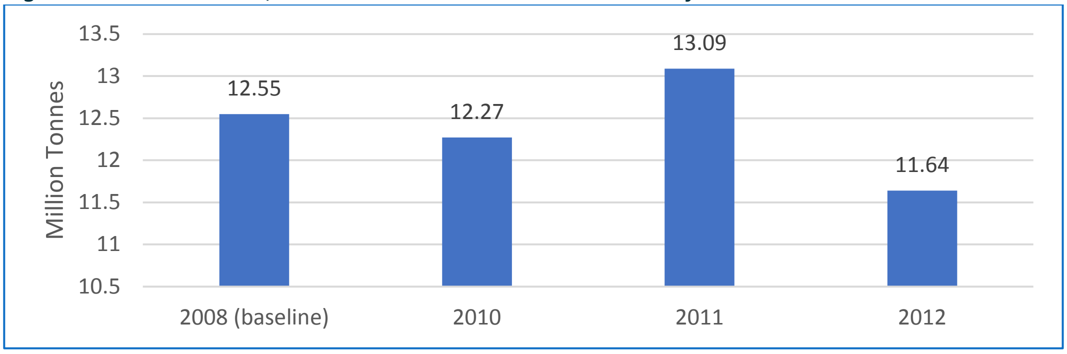
Source: Oakdene Hollins workup of Defra's UK statistics on waste data – December 2016 update, using a measure of sub-sector output listed in Table 57.

The analysis contained in the 2011 report shows that, in 2009, the no-cost/low-cost diversion from landfill opportunity was 6.5 million tonnes and the waste reduction opportunity at 1.17 million tonnes or 9.3% of construction product waste. The following sections will explore these two factors: diversion from landfill and waste reduction.

Diversion from landfill

Figure 30 shows the reported waste sent to landfill from the construction, demolition and excavation sector, with a 7% or 0.9 million tonnes reduction in waste to landfill between 2008 and 2012. Applying the annual landfill diversion rate of 0.225 million tonnes to the period 2009 to 2014 results in the 6.5 million tonnes estimate in 2009 reducing to 5.38 million tonnes in 2014.

Figure 30: Construction, demolition & excavation waste landfilled



Source: WRAP/Green Construction Board 2014, C, D & E Waste: halving construction, demolition and excavation waste to landfill by 2012 compared to 2008

Much of the waste generated within the construction sector would be regarded as inert waste that incurs the lower rate of landfill tax (£2.50 per tonne in 2014) and, when taking into account transport costs, labour costs etc., the value of savings in the 2009 study of £10.80 per tonne would appear to still be relevant. The savings associated with the 5.38 million tonnes would therefore be £58.1 million.

Waste prevention

A 2008 study by the Environment Agency (EA) estimated that 10 million tonnes of construction products per year are wasted due to the application of waste allowances to the quantity of materials ordered.[55] The EA placed a value on these wastes of £1.5 billion. More recent studies suggest that this is now nearer 13 million tonnes with the main reasons cited being over-ordering and onsite damage.[56]

Resource Efficient Scotland reports that no-cost/low-cost waste reduction interventions in the construction sector, such as reducing over-ordering or onsite damage, typically generate estimated savings equivalent to 1% of the overall construction costs.[57] The ONS reports[58] that the value of all new build construction in the UK in 2014 was £85,294 million which means the 1% saving equates to £853 million.

Table 35 summarises the savings in the construction sector.

Table 35: Summary of estimated savings in the construction sector

Intervention	Savings (£million)
Landfill diversion	58.1
Waste reduction	853.0
Total	**911.1**

However, a BRE study[59] states that the low awareness of the benefits of materials resource efficiency represents a significant challenge, and the business benefits of not producing

55 Environment Agency 2008, the economic and environmental benefits of resource efficiency in construction March 2008.

56 Sustainable build: reducing and managing waste. January 2013.

57 Resource Efficient Scotland. The business case for resource efficiency

58 The Office for National Statistics. Output in the construction sector. March 2017

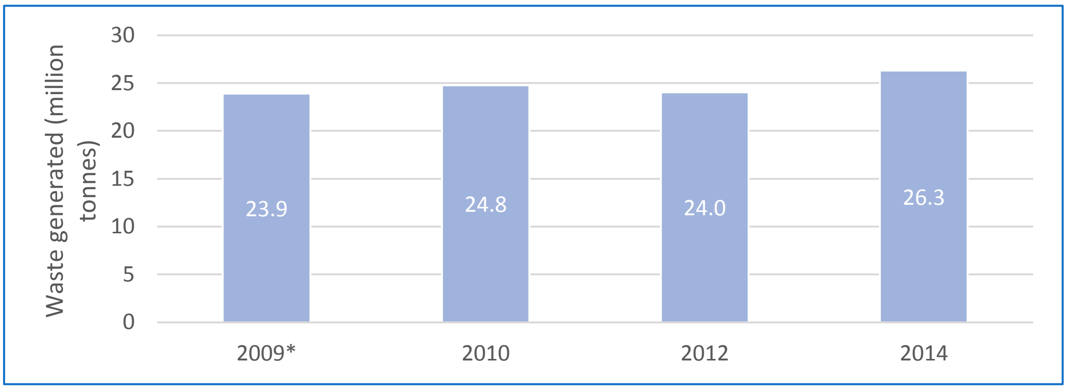
59 Material resource efficiency in construction: supporting the circular economy, Buidling Research Establishment, Published by HIS, Jan 2017

waste in the first place could be made clearer to all parts of the sector. The report also points out that contractors and subcontractors are not usually contractually obliged to eliminate or reduce waste.

4.4.4 *The mining and quarrying sector*

Waste from mining and quarrying is the second largest source of non-household waste in the UK. This is despite approximately two-thirds of the waste generated by the sector, as measured by the British Geological Survey[60], not appearing in the statistics compiled by Defra; we assume because it is backfilled or used in earth and road works at the site of extraction. Figure 31 shows that the waste generated fluctuated over the time period of 2009 to 2014.

Figure 31: Trends in waste generation in the mining and quarrying sectors



**2009 values were produced by casting Defra data from 2010, 2012 and 2014 back to 2009.*[61]
Source: Defra: UK statistics on waste data – December 2016 update

As depicted in Figure 32, total waste arisings in the sector have increased since 2009 even though output, based on the tonnage of non-energy minerals extracted in the UK, has declined by 7%.[62] Though the statistics suggest that there was approximately 18% more waste generated per tonne of mined or quarried product in 2014 compared to 2009, it is not clear whether this is due to changes in reporting practices or waste categorisation.

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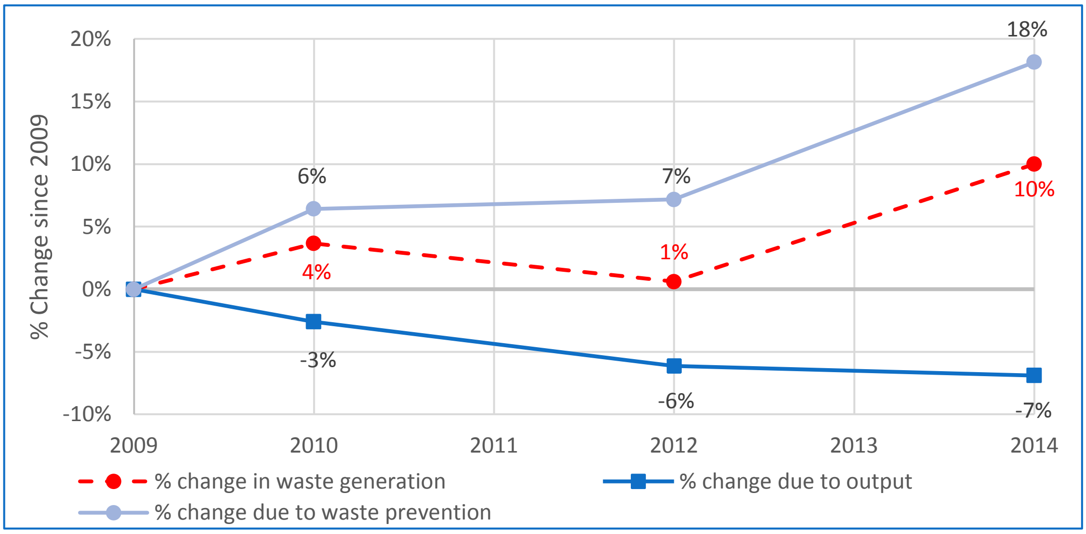
[60] Mineral waste in the UK: Innovation, optimisation and recycling. Presentation by Clive Mitchell, www.nora.nerc.ac.uk/513956/

[61] Straight line fit of 2010, 2012 and 2014 data used in projection.

[62] http://www.bgs.ac.uk/mineralsUK/statistics/ukStatistics.html

Figure 32: Change in waste generation in the mining and quarrying sector



Source: Oakdene Hollins workup of Defra's UK statistics on waste data – December 2016 update, using a measure of sub-sector output listed in Table 57.

The high levels of uncertainty in the data for the mining and quarrying sector mean that any estimates of potential waste savings are prone to inaccuracies and it is therefore suggested that further work is required on improving the accuracy of the data prior to the provision of the estimate.

4.5 Estimate of the waste savings opportunities in 2014

In summary, and as shown in Table 36, a total saving of £3,072 - £4,612 million could be achieved through implementing no-cost/low-cost waste reduction initiatives.

Table 36: Summary of the waste savings for 2014

Sector	Sub sector	Savings (£millions)
Services	Wholesale and retail	87
	Hospitality and foodservice	250
	Other	166
	Total	**418**
Manufacturing	Food and drink	192
	Chemicals	583 to 1,166
	Basic metals	388 to 776
	Other	610 to 1,149
	Total	**1,743 to 3,283**
Construction		911
Mining & quarrying		n/a
Total		3,072 to 4,612

4.6 Previous studies

Section 4.2 highlighted some of the challenges of estimating savings arising from waste reductions. There have been two previous Defra *Business Resource Efficiency* studies. A summary of each of the studies is included here.

The two previous studies can be seen to have taken very different approaches to valuing the savings opportunities associated with no-cost/low-cost resource efficiency interventions. In the first study, case studies and surveys were used to determine the savings potential which provided a level of reassurance that the savings opportunities could, in practice, be realised. The second study relied heavily on a modelling exercise where the base scenarios were not tested for there practical viability and hence the valuation can be considered to represent more the aspirational or theoretical opportunity.

4.6.1 *The 2007 Defra Resource Efficiency Study*

In the 2007 Defra Resource Efficiency study[63] the savings associated with waste, using a 2006 baseline, were calculated using a six step approach, namely:

1. Quantification of overall consumption; waste arisings (tonnes). Official Defra waste statistics as reported to Eurostat[64] as part of the EU Waste Statistics Regulation EC2150/2002 were used to generate the top level estimates and this was supplemented with sector or sub-sector level data from the Production Surveys undertaken by the EA.[65] These two data sources used the same sector and sub-sector definitions, namely: at sector level the 2-digit (division level) UK SIC and for sub-sector the 3-digit UK SIC (group level).
2. Quantification of waste savings (tonnes). Case studies and surveys were used to determine the potential savings, with the two main sources being the Envirowise FastTrack scheme and Enworks.
3. Conversion of physical savings (Step 2) into financial savings. Standard waste disposal costs (£/tonne) were determined at sector or sub-sector level with trade associations, delivery bodies and waste management companies being the key sources.
4. Addition of any hidden cost savings. This drew heavily from a study entitled 'Benefits of a Greener Business' produced by the EA.[66]
5. Grossing-up. It was not possible to cover all sectors or sub-sectors in Steps 1 to 4, and hence, a grossing-up stage was required. This involved applying the estimated mean savings (%) as a weighted average.
6. Regional analysis. The analysis involved splitting up the projected UK-level savings, derived in Steps 1 to 5, by government region.

Table 37 summarises the study findings. This shows that the estimated savings were £2,659 million with the food and drink sector (£858 million) and retail (£489 million) accounting for over 50% of the overall savings. In the retail sector the replacement of single-use cardboard by reusable packaging accounted for £480 million of the £489 million opportunity while the recycling of paper, card and plastic accounted for the remaining £9 million. These savings were taken from a study focusing on resource efficiency in the retail sector.[67]

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[63] Defra 2007, Quantification of the business benefits of resource efficiency. October 2007.

[64] Eurostat is a Directorate-General of the European Commission that provides statistical information to the institutions of the EU.

[65] The Commercial & Industrial Waste Production Survey. Environment Agency. September 2005.

[66] The Benefits of Greener Business (Cambridge Econometrics and AEA Technology) for the Environment Agency 2003

[67] The economic and environmental benefits of resource efficiency in retail. April 2006, Entec.

Table 37: Waste savings identified in the 2007 Defra report (2006 savings)

Sector	Sub-sector	Estimated savings		
		Reduction or recovery (%)	Without hidden savings (£M)	With hidden savings (£M)
Industrial	Construction	19.3	230	**239**
	Mining & quarrying	5.2	40	**40**
	Food & drink	19.3	94	**858**
	Energy supply	26.0	36	**45**
	Basic metals / Mechanical engineering	5.2	11	**17**
	Machinery, electrical & transport equipment	10.5	26	**195**
	Chem's, rubber & plastics	9.1	47	**235**
	Paper, printing & publishing	7.4	10	**20**
	Other	13.1	25	**83**
Commercial (Service)	Retail *et al*	9.0	118	**489**
	Travel agents and tour operator activity	10.8	68	**233**
	Hotels & catering	24.3	70	**70**
	Transport	13.4	12	**12**
	Education	20.0	53	**53**
	Misc service industries	2.8	24	**24**
	Other	12.0	17	**46**
	Total	**12.8**	**881**	**2,659**

Source: Defra. Quantification of the business benefits of resource efficiency. October 2007

Please note that, somewhat surprisingly, travel agents and tour operator activity was one of the most significant sectors with a savings potential of £233 million. This is due to the broad nature of this SIC code which also includes sporting activities, libraries, industrial cleaning, etc. It was estimated that the sector generated 9.62 million tonnes of waste in 2006/7 and that 60% was office-based waste. A 12% reduction in white paper use was considered a high value waste prevention option with an estimated saving of £165.6 million, representing 71% of the overall saving from the sector.

The waste resource efficiency opportunities identified for 2006 are shown in Table 38. In total, 38.7 million tonnes of opportunities were identified, of which 33.5 million tonnes (85.8%) involved better waste management, in the form of diversion of waste from landfill, with increased recycling being the prominent objective. The remaining 5.2 million tonnes (14.2%) of opportunities involved waste reduction in the form of at source waste prevention.

This heavy focus on the diversion of waste from landfill has a significant impact on the financial savings that are generated when measured in £ per tonne; the saving of £2,659 million associated with the 38.7 million tonnes equates to a saving of £69 per tonne. For reference, the study estimates that the cost of purchasing a tonne of white office paper is £1,200 and hence this would represent the savings potential from waste prevention. In addition, Table 38 shows that the diversion of the 19.7 million tonnes of construction waste from landfill represents the most prominent intervention in tonnage terms. However, when the labour costs associated with the segregating and processing of the recovered material are taken into account, the actual savings were valued at £10.80 per tonne.

Table 38: Identified waste resource efficiency opportunities by sector (Mt) in 2006

Sector	Resource efficiency intervention		Total
	Diversion from landfill	Waste reduction	
Agriculture & fishing	0.10	0.0	0.10
Construction	19.66	2.24	21.90
Mining & quarrying	4.85	0.0	4.85
Energy supply	1.90	0.0	1.90
Food, drink & tobacco	0.80	0.92	1.72
Textiles / wood / paper / publishing	0.38	0.27	0.65
Chemicals / non-metallic minerals	0.44	0.47	0.91
Metal manufacturing	0.25	0.0	0.25
Machinery & equipment (other)	0.76	0.0	0.76
Retail & wholesale	1.00	0.82	1.82
Public sector	0.49	0.02	0.51
Hotels & catering	0.75	0.32	1.07
Transport & storage	0.29	0.00	0.29
Other services	1.14	0.14	1.28
Waste management	0.67	0.0	0.67
Total	**33.48**	**5.20**	**38.68**

Sources: Oakdene Hollins & Grant Thornton for Defra (2007), Quantification of the business benefits of resource efficiency, & Oakdene Hollins for Defra (2009), Quantification of the potential CO_2 savings from resource efficiency in the UK

4.6.2 *The 2011 Defra Resource Efficiency Study*

The methodology used in the 2011 study[68] differed significantly from that in the 2007 study. Instead of building the estimates up from scratch, an activity based approach was used i.e. investigating the change in resource efficiency in each business sector since the 2006 baseline (determined in the 2007 study). The study states that this was considered a necessary change since a number of the datasets and sources used in the 2007 study had not been updated, and very few company- or sector-level resource efficiency case studies and site surveys were undertaken by delivery bodies (such as Envirowise) between 2006 and 2009, due to a change in government focus.

The general approach used within the study was:

1. Quantify overall waste generation by UK economic sector in 2009. This used the official Defra datasets using the same approach as in the 2007 study. This included Defra's 'Survey of Commercial and Industrial Waste Arisings 2009 for England'. These data were extrapolated to the whole of the UK using the national breakdowns of waste arisings from the 2006 included in Defra's submission to Eurostat.[68]
2. Determine the causative factors for any changes in consumption or generation since 2006, i.e. is the change in consumption/generation between 2006 and 2009 due to changes in sector output or intensity based changes (improved efficiencies)? The analysis of the trends in sector outputs was undertaken using GVA data for 2006 and 2009 from the ONS[69] UK National Accounts: Blue Book.
3. Quantify the no-cost/low-cost intensity based interventions (payback less than one year) realised between 2006 and 2009. This involved comparing the trend in waste generation (Step 1) with that of the trends in output (Step 2); i.e. the assumption was made that any difference between the volume of waste being generated and the change in output is due to a change in intensity, which can be considered a waste prevention intervention.
4. Determine the 2009 no-cost/low-cost resource efficiency opportunity using the information gathered in Steps 1 to 3, i.e. subtracting the resource efficiency improvements made between 2006 and 2009 from the 2006 baseline. A WRAP 2009 report[70] on the 'quick-win' materials savings was also used to derive the savings opportunity in 2009.

Table 39 provides a summary of the top 10 sub-sectors, in terms of waste savings opportunities, identified in the 2011 study. The results can be seen to show no resemblance to those shown for 2006 in Table 38 with the overall estimated saving of £18,260 million eclipsing the previous estimate of £2,659 million. The major cause of this increase was the inclusion of the findings from the aforementioned WRAP 'quick-win' study. 'C&I Landfill' is also included in Table 39 as a standalone sector, and this is due to the format of the Defra data which does not provide a sector-level breakdown of waste treatment end fates.

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68 Defra 2011, The further benefits of business resource efficiency. March 2011.

69 Office for National Statistics

70 Meeting the UK climate change challenge: the contribution of resource efficiency. Produced by the Stockholm Environment Institute and the University of Durham for the Waste & Resources Action Programme (WRAP), 2009.

Table 39: Summary of no-cost/low-cost waste savings opportunity for 2009

Sector	Savings opportunity (£M)
Chemicals / non-metallic minerals	4,396
Metal manufacturing	3,675
Power & utilities	3,499
Construction	2,601
Textiles / wood / paper / publishing	1,388
Transport & storage	912
C&I Landfill	445
Agriculture, forestry & fishing	362
Mining & quarrying	361
Food, drink & tobacco	219
Sub Total	**17,859**
Other	401
TOTAL	**18,260**

Source: Defra. The further benefits of business resource efficiency. March 2011.

Table 40 summarises the savings outlined in the 'quick-win' report. This shows a savings potential of £16,339 million, with 'lean' production being the most prominent form of intervention accounting for £12,429 million or 76% of the overall savings. In hindsight it is felt that these numbers should have been reported with a very high level of caution attached since the supporting assumptions appear ambitious (Table 41) and the interventions are considered technical and not quick-wins. For example, it is suggested in the study that the quick-win scenario for 'lean' production is the "material requirement to produce the same good is 15% less in 2020". It was stressed in the study that sector specificities could not be taken into consideration during the study due to the project constraints.

Table 40: Financial savings available for Quick Wins to 2020 by intervention (£M)[71]

Sector	Lean Prod.	Waste Red.	Recy-cling	Demat.	Build-ings	Infra-struct.	Total
Agriculture, forestry & fishing	36	84	31	206	4	2	**362**
Mining & quarrying	234	20	7	7	32	26	**325**
Food, drink & tobacco	8	54	19	136	1	1	**219**
Textiles/wood/paper / publishing	1,214	67	15	12	61	19	**1,388**
Power & utilities	2,222	574	225	112	192	164	**3,489**
Chems / non-metallic minerals	3,500	265	81	16	227	307	**4,396**
Metal manufacturing	2,329	133	31	8	80	101	**2,683**
Machinery & equipment (other)	65	8	-6	17	10	4	**98**
Construction	1,876	1	0	1	151	132	**2,161**
Retail & wholesale	87	4	1	5	7	7	**111**
Hotels & catering	4	0	0	0	0	0	**5**
Public Sector	19	1	0	1	2	1	**24**
Transport & storage	696	43	13	37	60	63	**912**
Other Services	138	2	1	2	11	10	**164**
Total	**12,429**	**1,257**	**419**	**559**	**838**	**838**	**16,339**

Source: Meeting the UK climate change challenge: the contribution of resource efficiency. Produced by the Stockholm Environment Institute and the University of Durham for WRAP, 2009.

[71] The WRAP data did not attribute the financial savings between sectors, so this has been performed here on the basis of the relative weights of the carbon savings for each of the interventions.

Table 41: Summary of Quick Wins scenarios used to model the savings opportunities

Resource Efficiency Strategy	Scenario
Lean production	Material requirement to produce the same good is 15% less in 2020
Waste reduction	15% of the raw materials from industry and commerce ending up in the waste stream are taken out of the economy by 2020
Re-direction of landfill materials	15% of the raw materials from industry and commerce ending up in landfill are recycled and put back into production by 2020
Dematerialisation of the service sectors	A third of discard rate is reduced for the different product groups, edible food is halved and junk mail is eradicated by 2020
Strategies for sustainable building	2% of the construction market is met by modular building design by 2020
Efficient use of existing infrastructure	Retrofitting 20% of housing deemed for demolition and vacant properties offsets the need for rebuilding by 2020

Source: Meeting the UK climate change challenge: the contribution of resource efficiency. Produced by the Stockholm Environment Institute and the University of Durham for WRAP, 2009.

For the purpose of consistency across the three surveys it is necessary to remove this 'hypothetical' element from the 2009 report and present the practical achievable savings which is eluded to in the term 'no-cost/low-cost'. The summary in Table 42 shows that this would reduce the overall estimate significantly, i.e. from £18,260 million to £1,922 million. Comparing the 2006 and 2009 valuations, this shows a reduction in opportunity of £737 million or 28% from £2,659 million in 2006 to £1,922 million in 2009. However, this cannot be classified as the rate of realisation of the 2006 opportunities since at sub-sector level there are significant changes.

For example, the savings opportunity in the food and drink manufacturing sector reduced from £858 million in 2006 to £219 million in 2009. Since we identified the savings potential from the food and drink manufacturing sector in 2006, much work has been undertaken to realise these savings. On the other hand, the full extent of the no-cost/low-cost savings opportunities in the hospitality and foodservice sub-sector were not determined until the comprehensive study undertaken by WRAP in 2013. Comparing the 2006 estimates to those of 2014, in the hotels sub-sector (hospitality and foodservice) the savings opportunity increased from £70 million tonnes in 2006 to £250 million in 2014.

Table 42: Summary of waste opportunities for 2009

Opportunity	£Million
Existing (remaining from 2006 estimates)	1,922
New	16,339
Total	**18,260**

5 Water

5.1 Quantification of water savings in 2014

Based on 2014 UK water data, water saving opportunities of £282.9 million have been estimated to be achievable as a result of no-cost/low-cost actions.

5.2 Sector level analysis of water consumption in the UK since 2009

This section focuses on the top five sectors identified in the previous study in terms of water reduction opportunities, namely:

- public administration
- agriculture
- food and drink manufacture
- education
- health and social work.

5.2.1 *Public administration*

A 2015 target under the HM Governments 'Greening Government Commitment' was to reduce water consumption from a 2009-10 baseline, and report on office water use against best practice benchmarks. The 2014/15 headlines were[72]:

- The Government reports an 11% reduction in water consumption against the 2009-10 baseline.
- 6 out of 22 departments met the challenging good practice benchmark for water use in offices.

In the 2011 resource efficiency study, it was estimated that there was a 26.5% water savings opportunity in this sector in the 2009 base year and hence the 11% reduction in water consumption would reduce the estimated savings opportunity to 15.5% in 2014.

5.2.2 *Agriculture*

Due to the nature of the dairy sector, with farms and manufacturing sites often tightly integrated, it was thought appropriate to include the dairy manufacturing sector in this section of the water chapter. The 2015 Dairy Environmental Benchmark report and the Dairy Roadmap 2015 state that the dairy manufacturing sector increased water efficiency by 15% between 2008 and 2014. The Dairy Roadmap reports that the relative water consumption reduced from 1.30 litres of water per tonne of milk processed in 2008 to 1.11 in 2014. Activities include:

- reducing freshwater abstraction
- water mapping projects to identify best practice
- rainwater harvesting
- water recovery through reverse osmosis
- optimising the efficiency of cip systems

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[72] HM Government 2015, Greening Government Commitments. Annual report April 2014 to March 2015.

- vehicle wash-water recycling
- low cost techniques such as employee engagement, triggers on hoses, dry floor cleaning and leak repair.

The achieved increase in water efficiency is considered even more significant taking into consideration the unprecedented increase in the number of products that processors are producing due to the changing demands of consumers and retailers, which has resulted in an increased need for 'clean-in-place' and therefore water.

The Business in the Community (BITC 2016) Smartwater study[73] provides examples of retailers and food manuafcturers placing water efficiency targets on their supply chains. For example:

- General Mills and Campbell Soup ask suppliers to complete a scorecard that includes a water use section.
- Unilever has an Agricultural Code of Conduct with a section on water use.
- Marks & Spencer has a 'supplier sustainability scorecard'. Over 90% of suppliers are participating in the programme, and together they have saved over 8.5 million cubic metres of water.
- Coca Cola, General Mills and Kellogg's have set time-bound goals to source the majority of their agricultural raw materials from farmers who use sustainable water management practices.

For the purpose of this study it is assumed that a 15% improvement in water efficiency was realised across the sector and hence 12.5% of the previous estimate of 27.5% remains.

5.2.3 *Food and drink manufacture*

The Federation House Commitment (FHC) was a major water reduction initiative operating in the UK food and drink manufacturing sector. The FHC was a voluntary agreement and ran between 2008 and 2014 and was managed by WRAP in partnership with the Food and Drink Federation (FDF) and Dairy UK, and supported by Defra and the Environment Agency. Figure 33 shows the trend in water intensity (excluding water in product) using a 2007 baseline. This shows that between 2007 and 2014 signatories reduced water consumption by 22.9%. Between 2009 (the base year of the previous resource efficiency study) and 2014 (the base year of this study) a 15% reduction in water use was realised. Please note: caution needs to be taken in interpreting the data since the datasets vary year-on-year depending on which sites report and the sub-sectors they represent.

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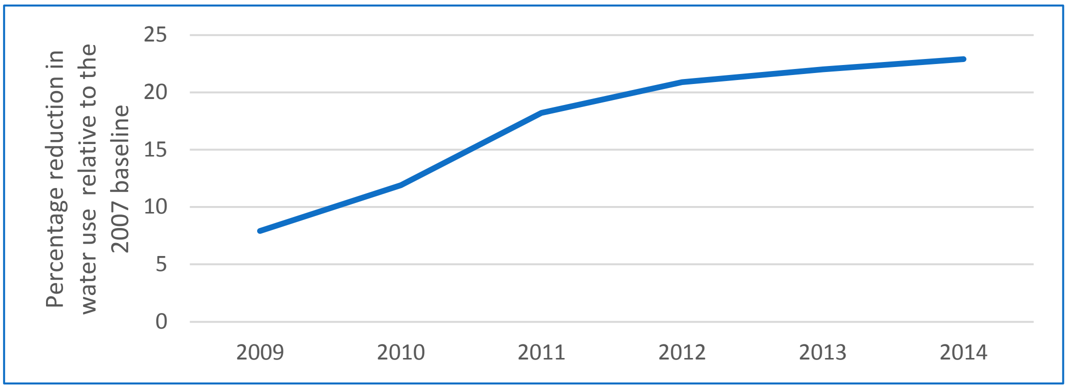
[73] BITC (2016). Smartwater: a prosperous future for the food and drink supply chain.

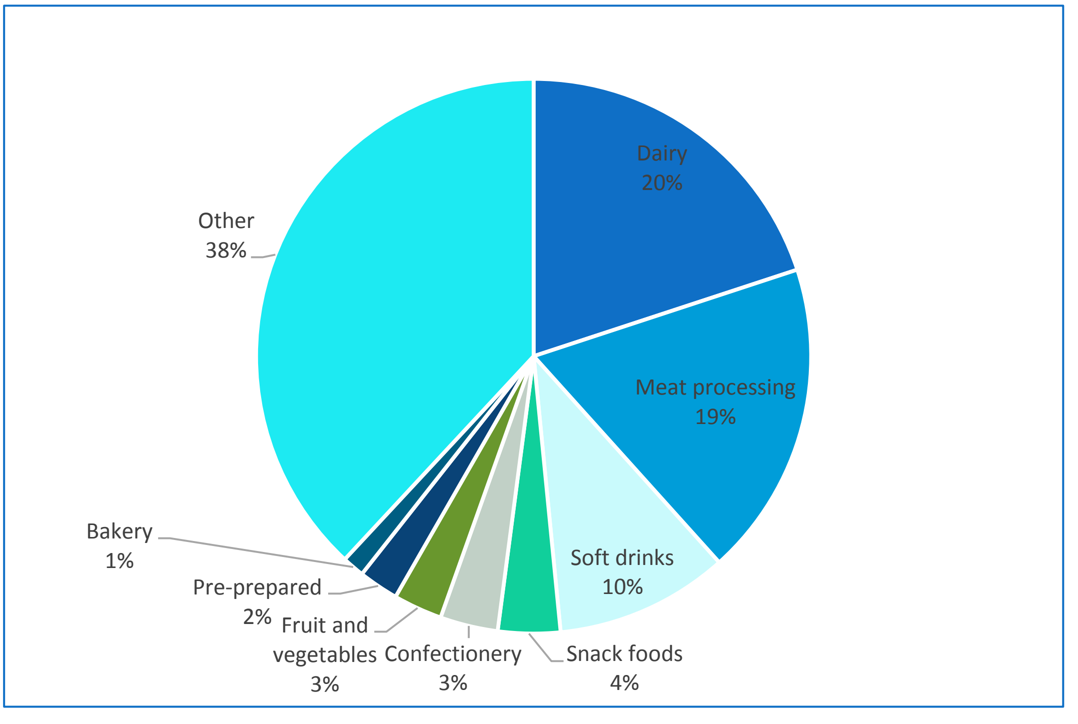
Figure 33: Water intensity trend (%age reduction in water use relative to the 2007 baseline)



Sources: WRAP 2011, The Federation House Commitment progress report 2011; WRAP 2013, The Federation House Commitment progress report 2013; WRAP 2014, The Federation House Commitment progress report 2014; WRAP 2015, food and drink water use reporting.

The 2013 FHC progress report estimated that in the 2007 base year the signatories represented 23-25% of UK food and drink manufacturing (based on water use), with total sector level water consumption of between 231 and 252 million cubic metres. In 2012, the FHC signatories accounted for 38.7 million cubic metres of water (excluding that in product). Figure 34 shows a summary of the 250 sites by sub-sector; three sectors - dairy, meat processing and soft drinks - account for nearly half (49%) of the water use reported by signatories.

Figure 34: Food and drink sub-sectors represented within the Federation House Commitment in 2012 (in descending order of water use)



Source: WRAP. The Federation House Commitment progress report 2013
'Other' includes: fish processing; alcoholic beverages; other non-alcoholic beverages; pet food and animal feed; milling; desserts; sauces and condiments; and other.

Whether these findings are representative of the rest of the food and drink manufacturing sector is difficult to quantify since there is a lack of relevant data beyond that captured by the FHC. Therefore an assumption is made that the 25% of the sector that is FHC members reduced the no-cost/low-cost opportunities identified in the 2011 study (15.5%) by 15% leaving a very modest 0.5% opportunity remaining in 2014. For the 75% of the sector (non FHC members) it is assumed that the opportunity identified in the 2011 study had halved by 2014, i.e. the savings opportunity had fallen from 15.5% in 2009 to 7.75% in 2014. This therefore represents an average savings opportunity remaining across the sector in 2014 of 5.94%, i.e. (0.25 X 0.5) +(0.75 X 7.75).

5.2.4 *Education*

Table 43 provides a summary of the findings from the Waterwise study of 2011. This shows the extreme variability in the water consumed per pupil per school.

Table 43: Water consumption in schools

School type	10% of schools have water consumption equal to or less than:	10% of schools have water consumption greater than or equal to:
Nursery	1.94 m^3/pupil	9.31 m^3/pupil
Primary	2.16 m^3/pupil	9.26 m^3/pupil
Secondary	1.87 m^3/pupil	6.34 m^3/pupil

Source: Waterwise 2011. Evidence base for large-scale water efficiency. Phase 2 final report. April 2011.

Table 44 provides an estimate of the water savings if the 10% highest water-consuming schools were able to move to the current mean practice. This assumes that this shift can be achieved through no-cost/low-cost interventions. The analysis shows a level of consistency with the savings potential falling between 3.5% and 4% across the three school types.

Table 44: Sector level water savings from moving the 10% highest water consuming schools to mean practice

School type	Assumed mean water consumption	Water saving potential moving the 10% of schools with the highest water consumption to mean consumption:
Nursery	5.625 m^3/pupil	4.0% of total water consumption
Primary	5.71 m^3/pupil	3.8% of total water consumption
Secondary	4.105 m^3/pupil	3.5% of total water consumption

Table 45 provides an estimate from the remaining 40% of schools that have an average water consumption above the mean consumption level. In this calculation it is assumed that the average consumption falls at the midpoint between the mean and the 10% level. For example, for nurseries the upper 10% level is 9.31 m^3/pupil (Table 43) and the mean level is 5.625 m^3/pupil so the midpoint is 7.468 m^3/pupil. This shows that the savings fall between 8.6% and 9.9%.

Table 45: Sector level water savings from moving the remaining 40% of schools with higher than average water consumption to mean practice

School type	Assumed water consumption	Water saving potential moving the remaining 40% of schools with higher than average water consumption to mean consumption:
Nursery	7.468m^3/pupil	9.9% of total water consumption
Primary	7.485m^3/pupil	9.5% of total water consumption
Secondary	5.223m^3/pupil	8.6% of total water consumption

Table 46 summarises the combined savings shown in Table 44 and Table 45.

Table 46: Sector level water savings from moving the 50% of schools with higher than average water consumption to mean practice

School type	Total water saving potential moving the 50% of schools with higher than average water consumption to mean consumption:
Nursery	13.9% of total water consumption
Primary	13.3% of total water consumption
Secondary	12.1% of total water consumption

The Waterwise (2011) study concludes that retrofitting water saving devices in schools is very cost-effective and offers a relatively quick payback. However, there are a number of barriers that discourage schools from undertaking these works independently, including:

- uncertainty over the level of savings for any specific school
- a lack of awareness and ownership of the issue.

WRAP (2012)[74] undertook a review of water efficiency opportunities at the University of Worcester. The review identified savings opportunities of 17%, with 12.2% being savings with a payback of one year or below. The two prominent no-cost/low-cost water savings opportunities, accounting for over 50% of the savings, were:

- Reduce shower flow rates to max 8L/min (accounting for 27.9% of the no-cost/low-cost savings).
- Reduce WC cistern volumes to 6L or 6.5L by the use of displacement devices (accounting for 23.2%).

Based on this analysis it is assumed that a 13% water savings opportunity remained in 2014.

5.2.5 *Health and social work*

The Department of Health (DoH, 2013)[75] reported that in 2001 the estimated financial savings that might be achieved through water efficiency measures, with little or no cost investment, was 20%. This translated into a possible saving of £9.5 million per year. The report also states that sewage accounts for over 50% of water and sewage costs which doubles the possible savings, in 2001, to £19 million per year. This would suggest that the valuation in the 2011 study of the potential saving for 2009 of 23.5% is an overestimate, since intuitively the savings would be expected to have reduced.

The DoH 2013 study included the results of a water audit undertaken at St Thomas' Hospital in London. The audit found potential annual savings of £72,322 or 35% of water costs (£206,860) of which £33,501 was classified as no-cost/low-cost, equivalent to 16% of water costs. Table 47 provides a summary of the no-cost/low-cost savings identified during the audit and highlights the significance of steam losses, which account for £26,846 of the £33,501 savings.

[74] WRAP (2012). University of Worcester, water efficiency review. November 2012

[75] DoH (2013). Environment and sustainability. Health technical memorandum 07:04. Water management and water efficiency best practice advice for the healthcare sector. 2013.

Table 47: Potential no-cost/low-cost potential water savings identified during a water audit at St Thomas' Hospital

Opportunity	Action	Cost saving (£/annum)	Estimated payback
Urinal flush control	Fit sensor-type flush control to existing urinals	2,137	9-12 months
Toilet cistern flush	Adjust ball-cock to reduce flush by 250 ml	489	Immediate
Leaking taps	Repair leaking tap in the sterile services department	980	Immediate
Steam losses	Maintain/repair release valves, traps, etc	26,846	Rapid
Endoscopy RO[76] overflow	Replace two small ball-cock units with one larger one to avoid jamming of float	1,544	Immediate
Condensate losses	Fix leaks (appeared to require simple gland tightening)	75	Immediate
Leaking pipes	Investigate and repair leak	980	Immediate
Blowdown cooling	Cool blowdown via a heat exchanger – not simple dilution cooling with fresh water	450	Immediate
	Total	**33,501**	

5.3 Estimate of water savings opportunities in 2014

OFWAT[77] reports that the changes in water charges were negligible over the period 2010 to 2015 and hence it is assumed that the same could be said over the period 2009 to 2014. The valuation of the savings opportunity in 2014 could therefore be derived by simply subtracting the realised opportunities from the 2009 estimates (Table 48).

Table 48: Estimate of water savings opportunities in 2014

Sub-sector	Water savings in 2009		Water savings 2014	
	Estimated savings (%)	Estimated total savings including wastewater (£M)	Estimated savings (%)	Estimated total savings including wastewater (£M)
Public administration	26.5	153.8	15.5	90
Agriculture	27.5	83.6	12.5	38
Food & drink	15.5	75.5	5.9	28.7
Education	23.5	36.8	13	20.4
Health & social work	15.5	26.6	16	27.5
	Sub total	**376.3**		**204.6**
Other sub-sectors		147.9		78.3
	TOTAL	**524.2**		**282.9**

76 Reverse Osmosis

77 OFWAT. Future water and sewerage charges 2010 – 2015: final determinations

5.4 Review of previous studies

Unlike the cases for energy and waste the methodology used in all three studies to quantify the savings opportunity for water has remained consistent. Table 49 provides a summary of the top sub-sectors in terms of the water efficiency savings opportunity shown for 2009 and 2014 shown in Table 48. This shows that, between the 2006 and 2009 studies, the estimated savings can be seen to reduce in all five sub-sectors but the actual financial savings increased significantly, i.e. from £441.3 million in 2006 to £524.2 million in 2009. This was due to a significant increase in the price of water between 2006 and 2009.

Table 49: No-cost/low-cost water savings opportunity 2006

Sub-sector	Water supply (input) savings		Estimated total savings including wastewater (£M)
	Estimated savings (%)	Estimated savings (£M)	
Public administration	31	66.3	85.8
Agriculture	32	37.8	37.8
Food & drink	20	34.3	60.0
Education	28	30.8	39.7
Health & social work	20	23.8	30.4
	Sub total	**193.0**	**253.7**
Other sub-sectors		108.6	187.6
	TOTAL	**301.6**	**441.3**

6 Conclusions and discussions

At the headline level the 2014 valuation can be seen to be in the same ballpark as the valuations for 2009 and 2006 (Table 50). However, this high level trend hides variations at the sector and sub-sector levels. These variations result from, for example, changes in data quality and an improved understanding of the true cost of waste (leading to increases in possible savings), or through efficiency savings realised.

Table 50: Summary of estimated no-cost/low-cost savings opportunities in 2006, 2009 and 2014

		Baseline year (£ millions)		
		2006	**2009**	**2014**
Energy	Freight	2,017	1,713	750
	Services	**Total n/a** Retail 141 Hotels 109 Commercial offices 101 Warehouses 77	**Total n/a** Retail 140 Commercial offices 101 Hotels 99	**Total 1,233** Retail 326 Warehouses 230 Hospitality 143
	Manufacturing	**Total 687** Chemicals *etc* 189 Basic metals 83 Food & drink 77	**Total n/a** Chemicals *etc* 90	**Total 346** Chemicals *etc* 101 Paper making 53 Coke et al 38
	Total energy	**3,349**	**3,820**	**2,329**
Waste	Services	**Total 927** Retail 489 Travel agents *etc* 233 Hospitality 70	**Total n/a**	**Total 503** Hospitality 250 Retail 87
	Manufacturing	**Total 1,493** Food & drink 858 Chemicals 235	**Total n/a** Metal manuf 992	**Total 1,743 – 3,283** Chems 583-1,166 Basic metals 388-776 Food & drink 192
	Construction	239	440	911
	Total waste	**2,659**	**1,922**	**3,072 - 4,612**
Water	Public admin	86	154	90
	Agriculture	38	84	38
	Food & drink	60	76	29
	Education	40	37	20
	Health & social work	30	27	28
	Total water	**441**	**524**	**283**
	TOTAL	**6,400**	**6,200**	**5,700 - 7,200**

What is clear, however, is that there are still savings to be made, even within the limits of no-cost/low-cost cost options considered within this study, that are advanteageous to individual companies and to the UK economy. To support the achievement of these objectives, several areas are worth considering:

- Improving data quality.
- Supporting structured approaches to improving resource efficiency.
- Considering measurement and indictors to track achievement.

6.1 Improving data quality

One of the significant limitations of this study is that is is heavily dependent on the quality and consistency of data. The valuation of the hospitality sector is a case in point. In 2006 the opportunity was valued at £70 million, but for 2014 it is valued at £250 million (Table 50). This is clearly not because the sector becoming significantly more inefficient, but due to a comprehensive study undertaken by WRAP in 2013 which provided a much improved estimate.

Construction, chemicals and basic metals are considered the high volume waste generating sectors with the highest level of uncertainty in terms of the value of the no-cost/low-cost resource efficiency opportunities, and hence similar research to that of the hospitality sector is recommended. Such surveys can then be used as a baseline from which to build a continual improvement work programme.

The research also showed that the intensity analysis was highly variable. For example, the energy analysis in the service sector and sub-sectors showed an unexplained spike between 2012 and 2014. Since this was observed in more than one sub-sector this suggests that this is a measurement issue rather than an actual change in sector / sub-sector level performance. As a result of this uncertainty, many of the estimates are based on case studies and surveys rather than on the official government statistics. One of the key reasons for this is that the official statistics are not targeting resource efficiency *per se*.

6.2 Strutured approaches to support resource efficiency

The research shows that the policy interventions targeting resource efficiency that have been most successful have involved the government or other governing bodies providing a coordination or facilitation role. In addition, they have three fundamental steps in place, namely:

- Set the baseline. Quantify the consumption in a set year and set this as the baseline year.
- Set reduction targets as a percentage of the base year.
- Regularly monitor performance and communicate best / good practice. This is typically documented in an annual report.

Examples of policy interventions that successfully adopted this approach are:

- For energy: The Climate Change Agreement (CCA) focused on the high energy intensive industrial sectors and the Logistics Carbon Reduction Scheme (LCRS) focused on road freight.
- For waste: the WRAP Courtauld Commitment focused on the food manufacturing and retail sectors and now expanded to the Hospitality and Foodservice Sector.
- For water: the HM Government's 'Greening Government Commitment' with one area of focus being placed on water consumption in public administration and the Federation House Commitment (FHC) focused on the food and drink manufacturing sector.

In Germany, a Raw Materials Strategy was adopted in October 2010 as a reaction to the challenges of a raw materials market that was increasingly being affected by trade restrictions, price rises and price volatility. The Strategy places emphasis on efficiency in raw materials extraction and processing, and on strengthening recycling.[78] As a result, German companies dominate in providing technological innovations for separation and recycling. They currently have 64% of the global market for automatic material separation technologies.[79] In addition Germany has a **National Research Strategy BioEconomy 2030 (2011)**[80] which outlines an approach to moving from an oil-based to bio-based industry, balancing technology and the environment.

6.3 Indicators to measure progress

From a dematerialisation or resource efficiency perspective, the key challenge is how to reduce the dependency or extraction rates of virgin feedstock. There are a number of international examples of national level indicators used to measure progress on resource efficiency, and currently some discussion around indicators suitable to measure progress towards a circular econonmy.

In the UK there is a heavy focus on recycling and, more specifically, the material collected for recycling as a percentage of the material placed on the market. However, this is not considered a robust indicator for measuring how much recycled feedstock (secondary raw material) is being used to displace virgin feedstock (primary raw material).

Table 51 provides examples of the types of indicators used in the German resource efficiency programme. The final indicator is of particular interest since it specifically targets primary material requirements.

Table 51: Examples of resource efficiency indicators used in the German Resource Efficiency Programme

Approach	Indicator
Continuous improvement in the resource efficiency of domestic production	Raw material productivity (GDP/DMI)
Increase in the use of recycled construction materials – recycled aggregates as concrete aggregate	Percentage of recycled aggregate used as concrete aggregate relative to total volume of mineral recycled construction materials
Increase in the high quality use of recycled construction materials – separation of gypsum from construction and demolition waste and establishment of recycling	Percentage of recycled material in manufacture of gypsum board (plasterboard)
Reduction in the primary material requirement (including for imported products) by the use of secondary raw materials (from which harmful substances have been removed)	Direct effects of recovery (DERec) as a percentage of direct material input (DMI)

Source: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. German Resource Efficiency Programme 2: Programme for the sustainable use and conservation of natural resources. November 2016

[78] Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. German Resource Efficiency Programme (ProgRess). February 2015.

[79] Wilts, H (2016) Germany on the road to a circular economy? Found at http://library.fes.de/pdf-files/wiso/12622.pdf

[80] National Research Strategy BioEconomy 2030 (2011). Found at: https://biobs.jrc.ec.europa.eu/sites/default/files/generated/files/policy/German%20bioeconomy%20Strategy_2030.pdf

Japan also has national programmes aimed at improving resource productivity and reducing waste.[81] Examples of indicators used at the national level to measure progress include:

- Resource productivity: GDP/input of natural resources.
- Cyclical use rate: Amount of cyclical use/amount of cyclical use + natural resources input. (Cyclical use rate in the context of this indicator refers to the use of secondary raw materials.)
- Final disposal amount: amount of waste to landfill.

Resource efficiency actions will continue to be significant for businesses resilience against a backdrop of the finite capacity of the planet to feed raw materials to global industries, absorb pollution, to meet the demands of population growth and of socio-political influences on the availability of critical raw materials. Analysis within this report demonstrates that there is still much to be gained at a business and a national level from a focus on, and progress toward, improved resource efficiency.

[81] Fundamental Plan for Establishing a Sound Material-Cycle Society, May 2013, reported to the Diet in accordance with Article 15 Provision 6 of the Fundamental Law for Establishing a Sound Material-Cycle Society.

Annex A Energy savings opportunity by sub-sector, 2009

Table 52: Summary of financial and CO_2 equivalent savings from low-cost energy efficiency measures 2009

Sub-sector	Savings opportunity (Ktoe)	Savings opportunity (£M)	Savings opportunity ($KtCO_2e$)
Chemicals, chemical products & man-made fibres	195	90	638
Food products & beverages	73	32	229
Non-metallic mineral products	50	15	161
Basic metals	71	40	270
Pulp, paper & paper products	45	20	146
Other Industrial	346	188	1,259
Total Industrial	**780**	**384**	**2,704**
Retail	164	140	704
Hotels	167	99	559
Warehouses	124	79	437
Commercial offices	152	101	549
Education	139	71	426
Government	135	72	422
Sports & leisure	36	24	130
Health	51	24	148
Communication	30	29	140
Other Service	54	33	185
Total Service	**1,053**	**673**	**3,701**
HGV – mainly public haulage	900	1,027	2,580
LGV – mainly public haulage	600	686	1,720
Mainly own account – HGV & LGV	920	1,050	2,630
Total Road freight	**2,420**	**2,763**	**6,930**
TOTAL	**4,253**	**3,820**	**13,335**

Annex B Summary of output and intensity energy trends in the commercial sector

Table 53: Summary of output and intensity change in the commercial sector 2009-14

	2009	2010	2011	2012	2013	2014
Energy consumption services (excl. agri) ktoe	18,763	19,590	19,155	19,362	19,774	18,056
Index of output (output)	100.0	99.6	100.7	102.9	103.5	107.2
Energy consumption services if output constant (excl. agri) ktoe (intensity)	18,763	19,671	19,017	18,808	19,101	16,842
Cumulative % change in energy consumption	0%	5%	2%	3%	5%	-3%
Cumulative % change due to output	0%	-0.4%	0.7%	2.9%	3.5%	7.2%
Cumulative % change due to intensity	0%	4.8%	1.4%	0.2%	1.8%	-10.2%

'Energy consumption per sub-sector' in ktoe for 2009-2014 taken from Table 5.05 ECUK
'Energy consumption per sub-sector if output was constant' calculated by dividing the energy consumption by the 'index of output'.
'Index of output' is the GVA (ONS) re-indexed to 2009. Sub-sector values used where available. A total 'index of output' for the services sector was taken as the weighted average (weighted to energy consumption) of the constituent sub-sectors.
Annual and cumulative change in 'index of output' allocate to changes in output. This was recorded in terms of Mtoe and % change.
Annual and cumulative change in 'energy consumption if output was constant' allocated to changes in energy efficiency (intensity). This was recorded in terms of Mtoe and % change.

<u>Energy price data</u>

Electricity, oil and natural gas account for at least 97% of the energy consumed by services (excl. agri). Non-domestic fuel prices found in government stats correspond to 'average price paid by manufacturers - not really service sector. 2009 values are between 19% and 24% lower than those used in the previous report.

Table 54: Fuel mix by sub-sector in the services sector in 2014

Sub-sector	Electricity	Natural Gas	Oil	Weighted average price (p/kWh)
Education	29%	55%	7%	
Government	32%	54%	6%	4.2
Health	24%	62%	3%	4.3
Commercial Offices	46%	45%	9%	3.8
Communication and Transport	82%	14%	1%	5.0
Hotel and Catering	38%	57%	4%	7.0
Other	40%	51%	9%	4.5
Retail	72%	26%	2%	4.7
Sport and Leisure	47%	52%	1%	6.3
Warehouses	40%	41%	20%	4.9
Total	**44%**	**45%**	**7%**	4.9
Non-domestic Energy price (p/kWh)	7.8	2.2	4.4	

Annex C Energy consumption in the industrial sector

The energy consumption per industrial sub-sector for every year between 2009 and 2014 is recorded in the Table 55. Note that due to the regular revision of the UK data on energy consumption, the absolute figures recorded here for 2009 are different to those recorded in the 2011 report.

Table 55: Summary of energy consumption in UK industrial sector 2009-14

Sub-sector	Energy consumption (Mtoe)					
	2009	2010	2011	2012	2013	2014
Coke and refined petroleum products	4.3	3.8	3.7	3.7	4.5	4.2
Chemicals	3.6	3.9	3.5	3.3	3.2	3.0
Food, drink & tobacco	2.7	2.9	2.9	2.9	2.9	2.8
Other non-metallic mineral products	3.0	2.7	2.5	2.4	2.5	2.5
Iron & steel, non-ferrous metals	1.9	2.1	2.1	1.8	1.9	1.9
Mechanical, electrical and instrument engineering	1.8	1.9	1.9	1.9	1.9	1.8
Paper, printing, publishing	1.7	1.7	1.7	1.7	1.7	1.7
Rubber and plastic products	1.2	1.5	1.3	1.3	1.5	1.5
Vehicles	0.80	0.92	0.94	1.0	1.0	1.0
Textiles, leather, clothing	0.78	0.82	0.81	0.79	0.78	0.77
Construction	0.60	0.67	0.66	0.65	0.67	0.66
Other*	3.0	2.8	1.9	2.0	1.0	1.6
Total	**25.4**	**26.2**	**24.4**	**23.9**	**23.9**	**23.8**

**incl. Water supply and treatment & waste collection and treatment; Mining and quarrying and Wood and wood products*
† Source: ECUK data Table 4.03

The fuel mix, presented in oil equivalents, for each sub-sector is recorded in Table 56. This information is used to convert from energy consumption to CO_2 emission and for calculating the cost savings for no-cost/low-cost resource efficiency interventions. The weighted average energy price per sector for 2014 was also calculated. Changes in fuel prices were assumed to have followed the consumer price indices for these fuels since 2009, and the average was weighted according to the fuel mix of the sub-sector.

Table 56: Fuel mix by sub-sector in the industrial sector in 2014

Sub-sector	Fuel mix in 2014 (in ktoe)							Weighted average energy price 2014 (p/kWh)
	Coal	Gas oil	Fuel oil	Natural gas	Elec-tricity	Mfd. fuel	Other*	
Coke and refined petroleum products	1,472	-	145	127	463	2,031	-	**3.0**
Chemicals	65	82	21	1,251	1,326	-	-	**6.0**
Food, drink & tobacco	45	33	84	1,761	915	-	-	**5.0**
Other non-metallic mineral products	808	44	-	1,208	420	-	-	**3.4**

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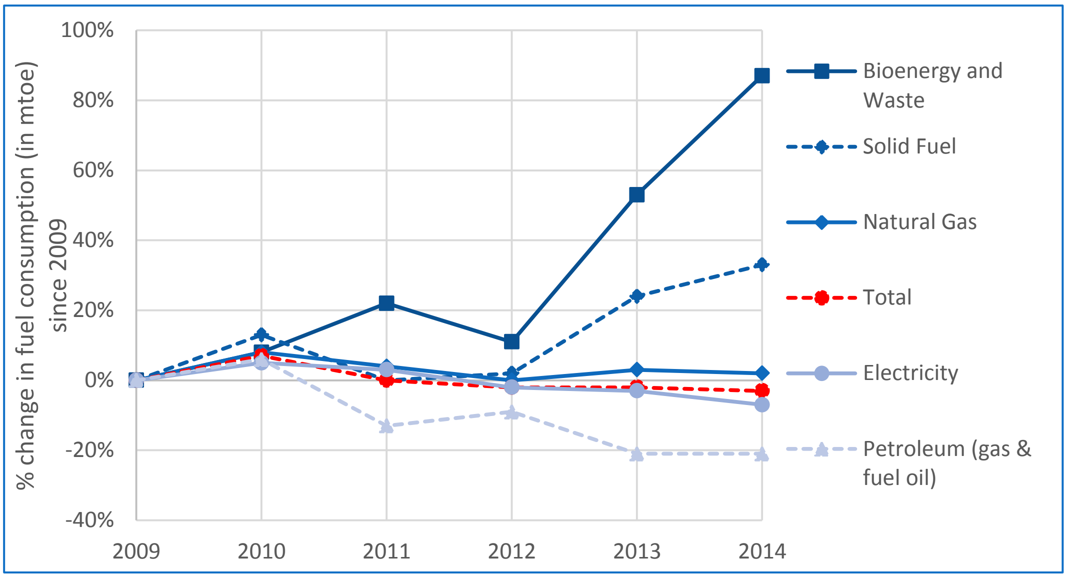
Iron & steel, non-ferrous metals	63	0	3	954	1,066	520	4	**6.1**
Mechanical, electrical and instrument engineering	5	1	-	403	730	-	-	**7.0**
Paper, printing, publishing	93	28	-	668	923	-	-	**6.3**
Rubber and plastic products	416	6	-	262	844	-	-	**5.9**
Vehicles	49	142	5	368	415	-	26	**5.8**
Textiles, leather, clothing	52	43	-	444	234	-	-	**4.8**
Construction	5	161	6	366	120	-	-	**4.6**
Other	-	1,220	31	342	983	46	2,559	**6.4**
Total	**3,075**	**1,760**	**295**	**8,153**	**8,440**	**2,596**	**2,589**	**5.3**
Average p/kWh (2009)	0.80	3.85	3.19	1.89	7.26			
Average p/kWh (2014)^	0.91	3.99	3.31	2.85	9.35			

**incl. liquid petroleum gas (LPG), burning oil, bioenergy and waste. Mfd. = manufactured.*
^calculated for 2014 by applying the change in the Consumer Price Index (CPI) between 2009 and 2014

The fuel mix used by the industrial sector has changed between 2009 and 2014 (Figure 35).

Figure 35: Trends in fuel mix in the industrial sector 2009 to 2014



The use of bioenergy and waste has nearly doubled but is still relatively small, accounting for only 3% of the total fuel consumed. The share of solid fuels, including coke, breeze and coal increased from 6.7% to 9.1% of the total fuel consumed, between 2009 and 2014. This is wholly due to a change in the reporting of fuel consumption for the coke and refined petroleum refining sub-sector between 2012 and 2013 (<32 ktoe in 2009-2012, and >3,500 ktoe in 2013-2014). There has been minimal change in the consumption of the two main fuels used in the industrial sector, natural gas and electricity, whilst consumption of the third most consumed fuel, petroleum, has decreased by approximately 20%. No industrial sub-sector split was available for petroleum consumption (only oil - where there was no significant change in overall consumption) so the reason for this decrease is unclear.

Intensity and output factors

To calculate the proportion of the energy consumption changes due to changes in sub-sector output (production) and intensity (energy efficiency) a measure of sub-sector output is required. One measure of sub-sector output is the GVA data reported in the ONS blue book.[82] It provides a relative measure of the value of sales associated with different sectors, including industrial and services. Using GVA, a financial measures of output, is not ideal for measuring a sector's material output as price volatility, as well as production volumes, affect the index. Also, the sub-sectors defined in the ONS data do not always align exactly with those used in the ECUK energy data. An index of sub-sector output, based on GVA and indexed to 2009 is presented in Table 57. Alternative production indices, based on production tonnages, were used instead of the GVA-based one where available, and are clearly marked and referenced below.

Table 57: trends in production output in the industrial sector 2009-14 (indexed to 2009)

Sub-sector	Index of production (2009=100)					
	2009	**2010**	**2011**	**2012**	**2013**	**2014**
Coke and refined petroleum products*	100.0	98.1	100.3	96.0	88.1	81.5
Chemicals^	100.0	95.0	88.5	84.6	82.8	81.1
Food, drink & tobacco^	100.0	104.2	111.0	108.2	106.4	111.3
Other non-metallic mineral products†	100.0	97.4	98.8	93.9	92.9	93.1
Iron & steel, non-ferrous metals^	100.0	106.0	110.7	113.9	110.6	113.0
Mechanical, electrical and instrument engineering^^	100.0	113.9	120.5	124.5	123.2	127.1
Paper, printing, publishing^^	100.0	100.5	95.8	91.7	93.8	93.2
Rubber and plastic products^^	100.0	97.6	96.8	98.3	94.5	106.1
Vehicles**	100.0	127.8	134.3	144.7	144.9	146.7
Textiles, leather, clothing††	100.0	103.1	104.3	100.7	96.0	101.3
Construction^^	100.0	108.6	111.0	103.4	104.8	113.2
Other^^	100.0	107.5	112.0	103.6	107.7	110.1
Avg (weighted by energy consumption)	**100.0**	**102.6**	**104.3**	**102.1**	**99.5**	**100.9**

**Table ET2.2, Solid fuels and derived gases statistics, DUKES Tables 3.2-3.4*
^Table 4.08 ECUK data 2016
^^Relative change in CVM[83] (£million) constant price from ONS Blue book
†Based on tonnage of non-energy minerals extracted as reported in the UK Minerals Yearbook 2015
***Society of Motor Manufacturers and Traders (SMMT) Motor Industry Facts Annual Reports contain data on car and commercial vehicle manufacturing volumes in the UK*
†† The changing-shape-of-uk-manufacturing---textiles[84] and Prodcom[85] data for 2014

From the index of production data above a measure of the change in energy consumption due to changes in production output can be derived (Table 58).

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82 www.ons.gov.uk/economy/grossdomesticproductgdp/compendium/unitedkingdomnationalaccountsthebluebook/2015-10-30
83 chained volume measure
84 webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/rel/uncategorised/summary/changing-shape-of-uk-manufacturing---textiles/sty---textile-industry-average-wage-lowest-within-uk-manufacturing.html
85 Prodcom provides statistics on the production of manufactured goods.

Table 58:Trends in production output in the industrial sector 2009-14

Sub-sector	% cumulative change due to output					
	2009	2010	2011	2012	2013	2014
Coke and refined petroleum products	0%	-2%	0%	-4%	-12%	-19%
Chemicals	0%	-5%	-12%	-15%	-17%	-19%
Food, drink & tobacco	0%	4%	11%	8%	6%	11%
Other non-metallic mineral products	0%	-3%	-1%	-6%	-7%	-7%
Iron & steel, non-ferrous metals	0%	6%	11%	14%	11%	13%
Mechanical, electrical and instrument engineering	0%	14%	21%	25%	23%	27%
Paper, printing, publishing	0%	1%	-4%	-8%	-6%	-7%
Rubber and plastic products	0%	-2%	-3%	-2%	-6%	6%
Vehicles	0%	28%	34%	45%	45%	47%
Textiles, leather, clothing	0%	3%	4%	1%	-4%	1%
Construction	0%	9%	11%	3%	5%	13%
Other	0%	8%	12%	4%	8%	10%
Average (weighted by energy consumption)	**0%**	**3%**	**5%**	**2%**	**0%**	**1%**

The change in energy consumption due to changes in energy efficiency (intensity) can be calculated by calculating the energy consumption at constant output (Table 59).

Table 59: Trends in production intensity in the industrial sector 2009-14 (using a 2009 baseline)

Sub-sector	% cumulative change due to energy intensity					
	2009	2010	2011	2012	2013	2014
Coke and refined petroleum products	0%	-9%	-13%	-11%	18%	21%
Chemicals	0%	13%	9%	9%	8%	4%
Food, drink & tobacco	0%	3%	-3%	-2%	0%	-6%
Other non-metallic mineral products	0%	-7%	-16%	-13%	-11%	-11%
Iron & steel, non-ferrous metals	0%	7%	-3%	-17%	-9%	-10%
Mechanical, electrical and instrument engineering	0%	-5%	-13%	-16%	-16%	-21%
Paper, printing, publishing	0%	2%	3%	6%	8%	8%
Rubber and plastic products	0%	25%	14%	9%	30%	20%
Vehicles	0%	-10%	-12%	-17%	-10%	-14%
Textiles, leather, clothing	0%	2%	0%	1%	4%	-2%
Construction	0%	2%	-1%	5%	6%	-3%
Other	0%	-1%	-28%	-14%	-56%	-46%
Average (weighted by energy consumption)	**0%**	**1%**	**-8%**	**-6%**	**-4%**	**-5%**

Overall energy consumption by the industrial sector decreased approximately 6% between 2009 and 2014. Energy intensity in industrial applications more than offset the small rise in output over the same period.[86] There were big differences in the energy consumption trends of industrial sub-sectors, some of the larger of which are discussed below.

Table 60: Review of energy consumption in the industrial sector 2009-14

	2009	2010	2011	2012	2013	2014

[86] AEA (2011), *Climate Change Agreements – Results of the Fifth Target Period Assessment*

Energy consumption all industrial (Mtoe)	25.4	26.2	24.4	23.9	23.9	23.8
Overall index of output (2009=100)	100.0	102.8	104.6	102.2	99.8	101.1
Energy consumption all industrial if output constant (Mtoe) <- intensity	25.4	25.5	23.4	23.4	24.0	23.5
Cumulative % change in energy consumption	0.0%	3.3%	-3.8%	-5.7%	-5.8%	-6.3%
Cumulative % change due to output	0.0%	2.8%	4.6%	2.2%	-0.2%	1.1%
Cumulative % change due to intensity	0.0%	0.4%	-8.0%	-7.8%	-5.6%	-7.3%

Cement production

Cement production is a major constituent of most modern construction projects and a major contributor to carbon dioxide emissions, though 60-65% of these emissions originate in the chemical decomposition of limestone into lime and not fuel consumption. The main fuels used in cement production are coal and petroleum coke, though the reliance on fossil fuels by the sector has decreased considerably, from 94% in 1998 to 60% in 2012. Each of the 9 million tonnes of cement produced in 2014 required approximately 110 kWh of power to produce. This is equivalent to 85 ktoe, and only a small fraction (3%) of the non-metallic mineral products sub-sector, in terms of energy consumption

In the DECC/DBIS report on a roadmap for decarbonisation and energy efficiency improvements in the cement sector there were no major no-cost/low-cost opportunities for energy efficiency improving interventions identified for the short term, 2014 to 2020. The major BAU emission reducing options, involving using alternative cements and substituting the raw materials used in the production of cement, were not expected to impact the sector until the medium to long term, 2020 to 2050.

In short, no no-cost/low-cost savings opportunities related to cement production were identified.

Glass production

Glass production in the UK is more than 3 million tonnes a year, spread over around 30 furnaces. Based on its energy consumption of approximately 560 ktoe per year (6,500 GWh) we estimate that glass accounts for approximately 23% of that of the non-metallic mineral products sub-sector. The melting and processing of glass is a high-temperature, and thus energy intensive, activity. Primarily supplied by natural gas, 85% of the fuel consumed by the sector is used to generate heat.

In the DECC/DBIS decarbonisation and energy efficiency roadmap report for glass CO_2 emission reduction opportunities equivalent to 3.5% of the sector's CO_2 emissions in 2014 were identified in the BAU scenario.

Table 61: Summary of the energy savings opportunities in the glass sector

Option	Emission saving opportunity by 2020 (% of 2014 emissions)
Waste heat recovery	1.3%

Improved furnace construction - conventional	1.1%
Improved process control	0.5%
Total	**3%**

The combination of these three energy efficiency interventions presents the opportunity to save 3% of the current energy used in glass production, equivalent to £5.5 million.

Table 62: Savings opportunities identified for the glass sector

	% industrial energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	**Energy consumption (ktoe)**	**Emissions ($ktCO_2e$)**	**Financial (£M)**
Glass production	2%	560	3%	17	44	5.5

The toe to tCO_2 conversion factor (2.6) and the average p/kWh (3.8) is based on the fuel mix in the sub-sectors in 2014. Also, 1 toe = 11,630 kWh.

Ceramics production

Based on its energy consumption of approximately 515 ktoe per year (6,000 GWh) we estimate that ceramics accounts for approximately 21% of that of the non-metallic mineral products sub-sector. Only one no-cost/low-cost opportunity that could be implemented on a short time timescale, 2014 to 2020, was identified.

Table 63: Energy savings opportunities in the ceramics sector

Option	Emission saving opportunity by 2020 (% of 2014 emissions)
Reduce radiant, convective and hot gas losses and leakage	1.1%
Total	**1.1%**

This intervention was estimated to equivalent to approximately 1% of the energy consumption of the sector in 2014. Based on the fuel-mix of the sector, primarily natural gas, the financial savings this corresponds to is £1.9 million.

Table 64: Savings opportunities identified for the ceramics sector

	% industrial energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	**Energy consumption (ktoe)**	**Emissions ($ktCO_2e$)**	**Financial (£M)**
Ceramics production	2%	516	1.1%	6	15	1.9

The toe to tCO_2 conversion factor (2.6) and the average p/kWh (3.7) is based on the fuel mix in the sub-sectors in 2014. Also, 1 toe = 11,630 kWh.

Savings opportunities in the paper, printing and publishing sub-sector

Approximately 4.4 million tonnes of paper products were produced in the UK in 2014. Energy consumption in paper production is dominated by that used in drying and is estimated to be approximately 4 MWh/tonne of paper produced, which is roughly equivalent to 1.5 Mtoe per year.[87] This indicates that paper production accounts for approximately 88% of the energy consumption in the paper, printing and publishing sub-sector. Printing and publishing will not be considered further in this analysis, only paper making.

The no-cost/low-cost options for emission savings in the paper making industry were equivalent to 14% of the 2014 emissions. Given the nature of these no-cost/low-cost options, see Table below, we assume that these emissions savings are directly proportional to energy saving measures.

Table 65: Energy savings opportunities in the paper, printing and publishing sectors

Option	Emission saving opportunity by 2020 (% of 2014 emissions)
Improved process control	3.3%
Extended nip press - non-tissue	3.9%
(Waste) heat recovery and heat integration	2.2%
Energy management	2.6%
Focus on maintenance	2.0%
Saturated steam system	3.3%
Total	**14%**

The savings opportunities identified for the paper making sector are equivalent to 211 ktoe.

Table 66: Savings opportunities identified for the paper making sector

	% industrial energy use 2014	Total energy consumption 2014 (ktoe)	No-cost/low-cost savings opportunities			
			Saving opportunity (%)	**Energy consumption (ktoe)**	**Emissions (ktCO2e)**	**Financial (£M)**
Paper making	6	1,510	14%	211	781	53

The toe to tCO_2 conversion factor (3.7) and the average p/kWh (2.1) is based on the fuel mix in the sub-sectors in 2014. Also, 1 toe = 11,630 kWh.

[87] https://www.carbontrust.com/media/206496/ctg059-paper-industrial-energy-efficiency.pdf?%7B13F23190-C09E-4fa6-8B23-8EF921B1E4E1%7D=aHR0cDovL3d3dy5jYXJib250cnVzdC5jb20vbWVkaWEvMjA2NDk2L2N0ZzA1OS1wYXBlci1pbmR1c3RyaWFsLWVuZXJneS1lZmZpY2llbmN5LnBkZg==

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With a degree in Theoretical Physics and a PhD in Materials Science, Nia's background is in nanomaterial research at the UCal San Diego and at the National Physical Laboratory, UK. She has a critical and thorough approach to analysing complex technical data sets, and the ability to concisely communicate complex topics. Recent work has been on which metals are critical to the EU defence sector, minor metals by-production, and an EU-wide project to assess the impact of nanotechnology funding.

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Olivia has worked as an environmental and corporate responsibility consultant for nearly 15 years. She has advised and assisted clients in identifying and managing significant corporate responsibility issues arising from stakeholder interest in corporate responsibility practices and performance. She is very experienced working with company directors, for whom issues of relevance, timeliness and quality are key, in particular with regard to public reporting.

Peter Lee PhD, Head of Operations

Peter has project-managed and written major studies on resource efficiency, sustainability, carbon reduction and energy, with much of his focus being on the food manufacturing and retail sectors. His specialisms include: waste prevention, waste logistics and reverse supply chains, packaging and waste management in the food and drink industry, environmental impact assessments, and recycling technologies. An expert in Lean techniques, he has worked with manufacturing clients to implement waste prevention.

Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Author	Editor
1	28/04/2015	1st draft	PL, NB, OB	KB
2	12/05/2017	Draft with additions and revisions suggested by DEFRA	PL, NB, OB	KB
3	19/05/2015	Final report with minor changes based on DEFRA recommendations	PL, NB, OB	DP

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