The Effect of Business Resource Efficiency on Employment and Competition

Risk & Policy Analysts Ltd.
Cambridge Econometrics Ltd.

A research report completed for the Department for Environment, Food and Rural Affairs

10/2010

RPA

cambridge econometrics

defra
Department for Environment Food and Rural Affairs

Published by the Department for Environment, Food and Rural Affairs

Department for Environment, Food and Rural Affairs
Nobel House
17 Smith Square
London SW1P 3JR
Tel: 020 7238 6000
Website: www.defra.gov.uk

Information about this publication is available from:
SCP&W Evidence Base
Defra
Zone 5D, 5th Floor, Ergon House
c/o Nobel House, 17 Smith Square
London SW1P 3JR

Email: scpevidence@defra.gsi.gov.uk

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Final Report to the Department for Environment, Food and Rural Affairs

10/2010

This research was commissioned and funded by Defra. The views expressed reflect the research findings and the authors' interpretation; they do not necessarily reflect Defra policy or opinions.

Report prepared by:

Rachel Beaven, CE Director
Philip Summerton, CE Senior Economist
Chris Thoung, CE Senior Economist
Cambridge Econometrics,
Covent Garden, Cambridge, CB1 2HS
United Kingdom
Tel: 01223 460760 Fax: 01223 464378
Web http://www.camecon.com

David Fleet, RPA Technical Director
Eszter Kantor, RPA Consultant
Meg Postle, RPA Director
Risk & Policy Analysts Limited,
Farthing Green House, 1 Beccles Road,
Loddon, Norfolk, NR14 6LT
Tel: 01508 528465 Fax: 01508 520758
Email: post@rpaltd.co.uk

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Glossary

CE	Cambridge Econometrics
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
RPA	Risk & Policy Analysts Limited
CVM	Chain Volume Measure

Executive Summary

Background

This project has been commissioned with two aims:

1. To identify a method by which the effect of resource efficiency measures implemented by businesses[1] on employment and competition can be determined; and

2. To test this method on two example sectors.

Through the analysis of specific businesses and the development of quantified modelling approaches, this study has examined the impact that low-cost/no-cost 'quick-win' resource-efficiency measures have on competitiveness and employment in sectors of the UK economy (specifically the example sectors, Food, Drink & Tobacco and Construction) and how these might affect the UK economy as a whole. The results provide Defra with a method through which it can assess the impacts of quick-win resource-efficiency measures on employment and competition, and a preliminary data set from which to target resource efficiency policy in the future.

The study commenced with a review of literature and evidence to: define the scope of the study; clarify the proposed method to be developed and tested; and propose the example sectors on which the method would be tested. The majority of literature reviewed does link resource efficiency to cost savings, and assumes that this directly results in increased competitiveness. Rarely though does the literature attempt to quantify the impact of resource-efficiency cost savings on competitiveness and on employment. The work done in this study is therefore pushing the research beyond the bounds previously reached.

The method developed and tested in this study comprised two key stages:

1. Preparation of detailed sector case studies; and
2. Application of two alternative modelling approaches.

Scope

For the example sectors, twenty five case studies were undertaken to better understand and quantify the relationship between quick-win resource efficiency and employment and competitiveness, and to gather data and evidence to be incorporated into the modelling work. The case studies used a combination of a specific and focused literature review, detailed consultation with companies in each sector and more general consultation with relevant industry and other organisations. The case studies collate a range of qualitative and quantitative data on the take-up and impacts of resource efficiency measures.

They essentially focused on the following aspects:

- the types of quick-win measures that have been implemented;
- the level of cost savings achieved;
- the changes in both the nature of employment as well as the number of jobs that may result from implementing resource efficiency measures; and

[1] As opposed to resource efficiency policies implemented by Government.

- the changes in the competitive position of companies as a result of any cost savings made due to the implementation of resource efficiency measures.

To quantify the impacts of quick-win resource-efficiency measures on competitiveness and employment we implemented two distinct modelling approaches to make best use of the information available:

- the development and application of a sector framework for sector-specific analysis;
- the application of a more complex whole-economy model (CE's MDM-E3 model of the UK).

Table 1 provides a summary of the characteristics of the two alternative modelling approaches. The sector framework is a comparative static framework designed to look at the one-off impacts of resource-efficiency on employment and competitiveness. It combines the case-study evidence and econometric relationships estimated for the example sectors. The whole-economy modelling approach makes use of Cambridge Econometrics' (CE) MDM-E3 model and also incorporates case-study evidence. The whole-economy model:

1. provides estimates of the impact on the industries supplying resources;
2. provides a complex framework allowing us to interpret the resource-efficiency savings in the context of whole-economy interactions;
3. is dynamic, allowing us to interpret the evolving impact of the resource efficiency savings over time.

By collecting information through literature review, case study analysis and a consultation process, we have identified the main reasons as to why companies implement resource efficiency measures, what types of measures are most characteristic of the example sectors and what the related costs and impacts on competitiveness and employment are. One of the limitations encountered during the case study analysis was that, at the individual company level, respondents found it difficult to quantify the costs of specific resource efficiency savings. Also due to issues of confidentiality as well as consultation fatigue, key staff were often not readily available to discuss the implications of these measures. Nonetheless from the information gathered on the types of quick-win resource-efficiency measures that have been adopted by companies, we have found that while businesses within the Construction Industry have tended to rely on raw materials savings due to the nature of their activities, the Food and Drink sector has not targeted raw materials (apart from packaging in relation to waste minimization) as a potential area of cost savings. Therefore, the following areas of resource efficiency activities have been focussed on by companies in both sectors to reduce costs:

- waste minimisation;
- water efficiency; and
- energy efficiency.

The case study examples indicate a wide range of impacts arising from low-cost/no-cost quick-win measures. Where the driving force behind the implementation of the measure is primarily cost cutting, increases in employment are unlikely; the primary focus of companies is to retain jobs, rather than create additional ones. For newly implemented resource-efficiency measures, enterprises are more likely to employ an external advisor initially and amend the job description of the appropriate member of staff to include the additional tasks. Where regulation and the improvement of competitive position are the forces for change, businesses are more prone to increase employment.

Table 1: Characteristics of the two alternative modelling approaches to quantify the impact of quick-win resource-efficiency measures on competitiveness and employment		
Characteristic	**Sector framework**	**Whole-economy model**
Purpose	Analyse the impacts on the sector in which the measures were implemented.	Analyse the impacts of sector-specific measures on the sector and on the wider economy.
Data/evidence incorporated	*Sector case studies*: estimates of resource-efficiency cost savings[2]. *Literature review:* alternative estimates of resource-efficiency cost savings[3]; findings informed the design of the approach. *ONS data* were collated and *econometric analysis* undertaken to identify relationships between: costs and prices; prices and trade/output; and output and employment.	*Sector case studies*: estimates of resource-efficiency cost savings. *Literature review:* alternative estimates of resource-efficiency cost savings[4]; findings informed the design of the approach. Application of *CE's MDM-E3 model* which incorporates.
Method for incorporating resource efficiencies	Only quick-win measures are incorporated. The measures are incorporated in aggregate, as a direct cost saving to the sector.	Only quick-win measures are incorporated. The measures are incorporated as reductions in inputs purchased by the sector (intermediate demand), allocated across those sectors that supply the inputs. The allocation can be varied to best represent the available estimates of resource-efficiency 'cost savings'.
Impacts measured	*For the sector in which the measures were implemented:* Price Imports Exports Output Employment – that resulting from any change in output (NOT changes in employment required to implement the resource-efficiency measures)	*For the sector in which the measures were implemented, for other sectors and for the economy as a whole:* Price Imports Exports Output Employment – that resulting from any change in output (NOT changes in employment required to implement the resource-efficiency measures) Other sector and macroeconomic indicators.
Analysis over time	Static framework. Results indicate the long-term[5] impacts.	Dynamic model. Results indicate the evolving impacts over time.
Strengths	Incorporates sector-specific characteristics. Delivers transparent, user-friendly tool.	Incorporates sector-specific characteristics. Quantifies second-round, economy-wide effects. Dynamic.
Weaknesses	Static. Quantifies only 'first-round' effects for a single sector in isolation.	Uses complex proprietary model.

[2] Case studies did not yield sufficient data/evidence to include in the sector framework: relationship between implementation of resource-efficiency measures and required employment (e.g. green jobs); relationship between costs and prices.

[3] Oakdene & Hollins and Grant Thornton (2007).

[4] Oakdene & Hollins and Grant Thornton (2007).

[5] In this case long term represents the period of time it takes for the economy to return to a steady state after the initial shock. The long term is therefore difficult to quantify but given the size of the shocks we would expect this to be between five to ten years.

Maintaining competitive advantage and financial sustainability remains one of the foremost drivers behind the implementation of quick-win measures. These measures therefore are often part of an integrated approach to reformulating production mechanisms and processes; they add to already planned benefits.

As would be expected, the low-cost/no-cost ‘quick-win’ resource-efficiency measures identified in the case studies yield fairly modest cost savings (see Table 2); this was the case also for those measures identified by Oakdene Hollins (2007). The Oakdene Hollins estimates of resource-efficiency savings from no/low-cost measures accounted for 0.2% of costs for the Construction sector, and 2.4% of costs of the Food, Drink & Tobacco sector. These may appear small savings but they amount to £254m for Construction and £939m for Food, Drink & Tobacco[6]. From the case studies for this project, the cost savings were estimated at 1.0% of costs (£1058m) for Construction and 0.9% of costs (£341m) for Food, Drink & Tobacco. However, our sector estimates are not as robust as the Oakdene Hollins findings because the sample size is substantially smaller.

Table 2: Resource Efficiency Savings

	Oakdene Hollins		Case Studies	
	£m 2005	% cost	£m 2005	% cost
Construction	254	0.24	1058	1.02
Food, Drink & Tobacco	939	2.36	341	0.87

Note that these estimates indicate that cost savings from quick-win resource efficiencies are not usually sufficient to reduce costs (year-on-year) but instead reduce the overall increase in cost. It should additionally be noted that given the current economic climate, it is perhaps more likely that any monetary gains from resource efficiency measures may be used to help companies balance their books, rather than invest in new employees or reduce prices.

Findings

Our two alternative modelling approaches were used to quantify the impacts of the resource efficiency savings made by Construction and for Food, Drink & Tobacco, by inputting either the Oakdene Hollins or our case study estimates of savings (as shown in Table 2). The impacts of these quick-win savings were modest in both the sector frameworks and the whole-economy model. For each sector, the results differ by modelling approach given the differences in design, scope and complexity of the two approaches. The results also differ depending on whether the Oakdene Hollins or case study savings were used, because the scale and nature of the estimated savings differ. Table 3 summarises the impacts on GVA and net trade (as indicators of competitiveness) and on employment.

The cost savings varied quite significantly between the two sets of data. For Construction the cost savings were identified as £254m from the Oakdene Hollins study and £1,058m from the case studies, whereas for Food, Drink and Tobacco these were £939m and £341m respectively.

[6] In 2005 prices.

Table 3: Impact of Resource Efficiency Savings (Levels)					
	WE/SF	Cost Saving (£2005m)	GVA impact (£2005m)	Net Trade (£2005m)	Employment (‘000s)
Oakdene Hollins					
Construction (S2a)	WE	254	319.9	n/a	-3.1
Construction (S2a)	SF	254	41.5	n/a	0.7
Food, Drink & Tobacco (S1a)	WE	939	1096.4	97.5	-2.0
Food, Drink & Tobacco (S1a)	SF	939	364.2	430.7	5.9
Case Studies					
Construction (S2b)	WE	1058	1216.6	n/a	-13.8
Construction (S2b)	SF	1058	173.1	n/a	3.0
Food, Drink & Tobacco (S1b)	WE	341	379.6	29.5	-1.1
Food, Drink & Tobacco (S2b)	SF	341	132.5	156.6	2.1
Note(s): WE = whole economy modelling, SF = sector framework. S1a – Food, Drink & Tobacco, Oakdene Hollins S1b – Food, Drink & Tobacco, Case Studies S2a – Construction, Oakdene Hollins S2b – Construction, Case Studies					

The results show mixed impacts of resource efficiency on employment and competitiveness. In the first-round of impacts, the cost savings are passed through to reductions in price; the analysis for the sector frameworks showed that in both the Construction and the Food, Drink & Tobacco sectors, the rates of cost pass-through were close to (100%)[7]. Lower prices then boost demand and output. These first-round impacts point to overall gains, albeit modest, in both competitiveness (as measured by increases in GVA, profit and trade) and employment. The analysis in the sector framework stops at the first-round impacts.

So, when considering the Oakdene Hollins results in the sector framework for Construction, a £254m cost saving leads to a £41.5m increase in GVA, as most of the cost saving is passed on to consumers but the price change results in only modest increases in demand. The intuition is that firms compete with each other within the sector to reduce prices, but the overall level of demand for Construction does not increase much as a result of the overall sector price change. The small change in output leads to a modest increase in employment of around 700 FTEs because the sector is reasonably labour intensive.

For Food, Drink and Tobacco, we see an increase of £364m to GVA as a result of the £939m cost saving. So again, we observe that firms compete to drive down sector prices but at a sector level the impact of a price reduction on demand is modest. However, for Food Drink and Tobacco there is an impact on net trade, as UK exports become cheaper and domestic prices become more favourable relative to import prices; as a result, net trade increases by £430.7m. Due to this increased output, we see a proportionally smaller increase in employment of around 5,900 FTEs.

The results of the whole-economy approach, which takes account of inter-industry linkages and thus represents a more complex system for analysis, suggest that the policy implications are not so clear-cut because of secondary effects. The assumption made about the

[7] i.e. the cost savings were almost entirely passed on to reduced prices; these quick-win gains were not used to finance investment.

resource-efficiency savings is that a sector is able to maintain output by using fewer inputs (e.g. by better supply-chain or waste management). The resource efficiency savings are therefore incorporated as reductions in inputs purchased by the sector (intermediate demand) and are allocated across those sectors that supply the inputs so as to best represent the nature and scale of the different estimates of resource-efficiency 'cost savings' (from Oakdene Hollins and the case studies). As a result, the analysis precludes the possibility of opportunities arising from the development of 'green' businesses associated with a more resource-efficient economy that may also lead to new jobs. The principal obstacle to quantifying such opportunities is attributed to the absence of, and difficulty in collecting, such data.

The whole-economy approach takes account of secondary impacts on the wider economy, e.g. reduced demand for the supply-chain sectors, and the associated reduction in employment and incomes, and also the economy-wide impacts of changes in prices. The results of the whole-economy approach suggest that the first-round effects can be outweighed by secondary effects, implying that income effects can be larger than the price effects that result directly from the resource-efficiency savings. The analysis undertaken in the whole-economy approach focuses on the impacts of adopting resource-efficiency measures in the two sectors selected for study only. Other sectors do respond to the changes in demand for production inputs in the model but no explicit efficiency measures are modelled in other sectors; the impact of economy-wide measures has not been assessed.

For the Food, Drink & Tobacco sector, the whole-economy approach indicates that the secondary feedbacks from the rest of the economy mitigate some of the first-round impacts. In the case of Food, Drink & Tobacco, lower costs lead to lower prices and this stimulates additional demand. The sector's output increases, as does its GVA (in 2005 prices, by £1.1bn in 2015 when compared to an alternative scenario in which there are none of the resource-efficiency savings identified in the Oakdene and Hollins study). A more price-competitive UK Food, Drink & Tobacco sector is reflected in an implied improvement in the trade balance arising from the efficiency measures.

For the Construction sector the secondary impacts serve to magnify the first-round impacts. The results of the sector framework show that GVA and employment are boosted by the first-round impacts of resource-efficiency measures. However, in the whole-economy model, the impact of reducing resource inputs leads to a reduction in intermediate demand, which in turn leads to reductions in output from a number of sectors that supply inputs to Construction. This leads to a reduction in value added and incomes in other sectors of the economy, which more than offsets the increases in demand for Construction brought about by lower prices. The implication is that the impact on the Construction industry is a reduction in prices and an increase in demand, when viewed in isolation (and GVA does increase, by £320m based on the Oakdene and Hollins figures, because material costs account for a smaller share of total costs), but once the wider impacts are accounted for, output suffers. These secondary impacts dominate the price effect for two reasons: the Construction sector relies on a large supply chain and so the multiplier effects as a result of a reduction in intermediate demand are substantial; and because the price elasticity of demand for the Construction sector is quite small as it is driven principally by economy-wide growth and investment.

The employment responses of the sectors vary. In Food, Drink & Tobacco, cost savings reduce industry prices and boost demand and output; but to produce the higher output labour productivity (hours worked) is increased and so employment is not increased. This contrasts to the results from the sector framework which show an increase in employment in line with the required increase in production (because the nature of labour in the sector frameworks is simpler). In Construction the decrease in output yields an associated decrease in the number of people employed. Depending on the size of the savings modelled, the employment reduction was between 3,000 and 14,000 FTEs.

Overall, the results of the modelling give impacts on competiveness and employment which are quite modest in scale when compared to the economy as a whole. This reflects the modest scale of quick-win resource-efficiency savings and also, to some extent, the characteristics and limitations of the modelling approaches that have been developed and tested (see below). The likely impacts on individual sectors and individual businesses though have the potential to be much greater.

The analysis suggests that the impact of resource efficiency on the economy is likely to vary considerably depending on the characteristics of the sectors concerned, namely:

- the positioning of the industry with regard to final product supply chains;
- the import intensity of the resources whose demand is reduced;
- the types of resource efficiencies (the extent of the intra-industry feedbacks);
- the price elasticities of demand (and trade demand);
- the degree of influence of the business cycle on demand for the sector;
- the cost pass-through rate; and
- labour market interactions influenced by the business cycle.

In comparing the results of the two approaches, it would appear that the sector framework is perhaps too limiting as an approach to inform policy. While the sector framework maintains the advantage of transparency and provides an analytical structure in which to consider resource efficiencies, it is unable to deal with a number of complexities that must be considered when analysing impacts on the economy as a whole. This would be even more imperative when considering resource efficiencies which arise from substantial capital investments.

By contrast, the whole-economy model is complex and allows for conclusions to be drawn in the light of a fuller consideration of the potential impacts. Furthermore, it allows for the interpretation of unintended consequences (an important feature of policy impact analysis). The principal downside of this approach is that it requires a large amount of time and expert use to interrogate and interpret the results of the model, while the sector framework is almost immediately intuitive.

In the whole-economy approach, the cost savings essentially represent better waste and supply-chain management. However, within this study, it has not been possible to take account of the potential gains to supply-chain industries such as recycling and waste management within the whole-economy model.

In addition, the content of the study has met with certain limitations that are described in detail under Section 2 of this report. The sector framework is necessarily limited to analysing the first round direct effects within a sector. However, we were highly aware of this at the design stage and proposed that we also model the resource efficiency savings in CE's whole economy model of the UK, MDM-E3. The case studies, while developing interesting company level conclusions on the impact of resource efficiency, did not return as much information as had hoped and would have ideally been available for the sector framework and whole-economy modelling. The solution to this was also to make use of estimates of cost savings from previous studies and to compare the model results with those that used the case-study estimates.

In order to improve the quality of available data and further research in the field of resource efficiency, it would be necessary to conduct regular assessments of businesses so as to infer the extent and use of savings mad, as well as to pick up on whether 'green' jobs were required to implement the resource efficiency measures and to identify any competition-related benefits of the implemented measures.

Current legislation affecting the use of resources within the relevant sectors are summarised in detail within the case studies in Annex C and D. While it may be difficult to show direct correlation between the impacts on employment and competitiveness, it is important to highlight regulations that act as the leading drivers of change to resource efficiency in individual sectors and across the UK economy as a whole. It is essential that the regulatory framework governing industries finds an appropriate balance between encouraging cost-effective growth and ensuring environmental protection. It is in the interest of both the industry and the regulatory bodies to identify the procedures relevant for the sector that are most in need of additional incentives as well as to simplify the processes and requirements of policies without a risk to environmental effectiveness or health and safety.

1 Aims and Context

This study has been commissioned under the Sustainable Consumption and Production (SCP) Evidence Programme with the aim of mapping out patterns in sustainable consumption and production and identifying the impacts of resource efficiency measures implemented by UK businesses.

The UK Government has committed itself to achieving targets for reducing greenhouse gas emissions. This commitment is given in the Climate Change Act 2008, which provides the legally binding framework for decreasing all greenhouse gas emissions by at least 80% by 2050. It is recognised that these reductions will require contributions across all sectors of the economy. According to a study undertaken for Defra in 2009, between 29 and 38 million tonnes of CO_2 can be saved annually through a combination of energy, water and waste efficiencies throughout all sectors.[8] This figure represents a saving to the economy of around £6.4billion[9] and equates to more than half the average year-on-year growth in profitability of the total UK economy that was achieved in the 5 years to 2007.[10]

As resource efficiency measures are key ingredients of a sustainable production mechanism, incentives towards their wider application can contribute to realising win-win situations for the economy and the environment. Policies aimed at increasing the implementation of resource efficiency measures can significantly impact production costs and therefore the market position of businesses, which on a larger scale might accelerate economic growth and improve international competitiveness.

Although resource efficiency measures may have positive impacts on the competitive position of and level of employment in businesses, some forms of resource efficiency – as companies rationalize their resource use and production approach - may actually result in a number of job losses (e.g. companies might employ one waste contractor for multiple sites instead of previous practices of one person per site). Consequently, as business resource efficiency measures are being increasingly adopted by companies and promoted by government, there is a need to be able to clearly identify the nature and scale of both positive and negative effects on employment, as well as those on competitiveness. This will help ensure that government is in a position to identify and promote appropriate polices (including ones which can mitigate any negative effects of particular resource efficiency measures) whilst being fully aware of their consequences.

This project therefore had two main aims;

1 To identify a method by which the effect of resource efficiency measures implemented by businesses[11] on employment and competition can be determined; and

2 To test this method on two example sectors.

8 Quantification of the potential CO2 savings from resource efficiency in the UK, Oakdene Hollins, May 2009

9 Defra project EV02036 - Quantification of the business benefits of resource efficiency, Oakdene Hollins, October 2007

10 Competitiveness improvements potentially available from resource efficiency savings, Oakdene Hollins, May 2009

11 As opposed to resource efficiency policies implemented by Government.

The initial scoping stage of the project undertook a review of literature and evidence in order to define the scope of the study and to clarify the proposed method to be developed and tested. It was agreed that the focus of the study would be on short term quick-win resource efficiency measures approaches including:

- **Energy** - savings achieved by switching off lights and equipment when not in use, changing light bulbs to energy saving alternatives, reducing transport miles, fitting timers to devices and decreasing office temperatures;

- **Material –** reducing raw materials demand by reusing materials where possible, minimising off-cuts in the production process, fitting remould tyres to vehicles, etc.;

- **Waste** - reducing waste generation and increasing recycling by undertaking regular waste audits, preventing spillage and cross contamination of materials and products, separation of wastes and recovery of inputs for cleaning and re-use (e.g. cooling liquids); and

- **Water** - reducing water consumption by using percussion taps in staff washrooms or collecting and treating rainwater for industrial purposes.

Case studies have been undertaken to investigate the nature of quick-win resource efficiency measures and to gather estimates of resource efficiency cost savings; two alternative modelling approaches were then developed to quantify the economic impact of resource efficiency measures. Information on the extent of savings as well the key focus of the measures implemented by companies can be found under Annex C-D of this report.

The aim of the study was to develop and test a method to identify how such resource efficiency measures may impact on the overall economy; thus, the study has looked at the potential benefits resulting from a more competitive market environment and the impacts of this in stimulating economic growth. Competitive markets tend to yield incentives to cut prices and to improve productivity. The case studies provide a more detailed assessment of the relationship between resource efficiency and cost savings; their analysis allows for a comparative interpretation of the impacts of cost savings between the two example sectors. The two modelling approaches developed and tested provide methods to quantify the impact of the cost savings associated with resource efficiency on employment and competition; by design, the modelling approaches are a stylised representation of how individual industry sectors and the wider economy respond to resource efficiency measures.

2 Methods and Approach

2.1 Overview of Approach

2.1.1 Introduction

This section of the report sets out the overall approach taken to the study. As noted in the previous sections, our approach has been based on a combination of literature review, case study work together with the development and application of a more quantitative modelling approaches based on econometric modelling.

Discussions with Defra at the kick-off meeting indicated a preference for sectors characterised by “resource inputs into production processes” rather than by the extraction of resources. The selection of sectors for testing the model is based on sets of criteria, covering both the relevance of the sector and its suitability in relating to the needs of the model. Criteria focussing on sector relevance include:

- type of environmental impact - one sector should have its environmental impact split roughly equally between energy, water and waste arisings while the other should have waste arisings as the major source of its environmental impact;

- potential for resource efficiency gains - the chosen sectors should have a high potential for resource efficiency gains as this may offer the opportunity for the Government to focus on these sectors first and will also maximise the likelihood that the impacts will be measurable in any model; and

- relevance to Defra’s policy remit - the sectors should preferably be within Defra’s policy remit, so that any findings or recommendations can be acted upon (we anticipate this aspect to be further discussed with Defra following the submission of the report and it is therefore not analysed further here).

Those sectors identified by Oakdene Hollins (2007) as having the highest potential for resource savings (analysed separately for each resource) are given in Table 2.1 below.

Defra selected the two sectors to act as the basis for the case studies and to be examined in the modelling. These are:

- the Food, Drink and Tobacco sector; and
- the Construction sector.

In order to quantify the level of savings that companies have achieved (or could in the future achieve) within the specific sectors and to define the impacts that quick-win measures have on competitiveness and employment, the project work started with a systematic review of the literature related to resource efficiency, its wider economic impacts and the methods used to assess these impacts. The findings of the literature review provided the baseline against which case study results and econometric modelling results can be measured and compared.

Table 2.1: Sectors with highest savings potential from low-cost/no-cost measures		
Activity	**Estimated Savings Opportunity (£M)**	**% of overall savings**
Energy		
Transport (road freight)	2,017	60.3
Chemicals, rubber & plastics	189	5.7
Retail	141	4.2
Hotels & Catering	109	3.3
Commercial offices	101	3.0
Basic metals / mechanical engineering	83	2.5
Food & Drink	77	2.3
Warehouses	77	2.3
Waste		
Food & Drink	858	32.3
Retail	489	18.3
Construction	239	9.0
Chemicals, rubber & plastics	235	8.8
Travel agents	233	8.8
Machinery, electrical & transport equipment	195	7.3
Hotels & Catering	70	2.6
Water		
Public administration	85.8	19.4
Food & Drink	60	13.6
Education	39.7	9.0
Chemicals, rubber & plastics	38.9	8.8
Agriculture	37.8	8.6
Health & social work	30.4	6.9

Source: Oakdene Hollins 2007
Note: Yellow highlights indicate subsectors of secondary industries.

The next stage of work involved preparing the two detailed sector case studies. This was carried out through a combination of more specific and focused literature review, detailed consultation with companies in each sector and more general consultation with relevant industry and other organisations. The case studies collate a range of qualitative and quantitative data on the take-up and impacts of resource efficiency measures.

Finally, the study developed and tested two alternative modelling approaches to estimate the impact of the quick-win resource-efficiency measures identified by the detailed sector case studies and the literature review.

The first modelling approach developed a sector framework to quantify, for a sector as a whole, the impacts on employment and competitiveness of quick-win (low/no cost resource-efficiency savings) resource-efficiency measures implemented at company level (and scaled to sector level). The case studies were designed to gather evidence on the resource-efficiency measures, and their relationship to qualitative changes in job specifications, innovation activity and profit retention (see Section 2.3). The sector frameworks also incorporated the results of econometric estimation, as laid out in Section 2.4 of this report, to make quantitative estimates of the impact of resource-efficiency measures within the sector. By combining the case-study evidence and the econometric relationships we have developed a simple sector framework assessment tool, in spreadsheet form.

The second modelling approach was to apply a more complex whole-economy model (CE's MDM-E3 model of the UK) to assess to impact of quick win(s) measures on the whole economy; this approach allows for whole-economy interactions, namely, intermediate demand impacts and the relationship between wages and prices. This was designed to capture the spillover impacts on the wider economy of the resource-efficiency measures implemented in the specific sector, to assess potentially wider shifts in employment, competitiveness, GVA, etc. The modelling approach is described further in Section 2.5.

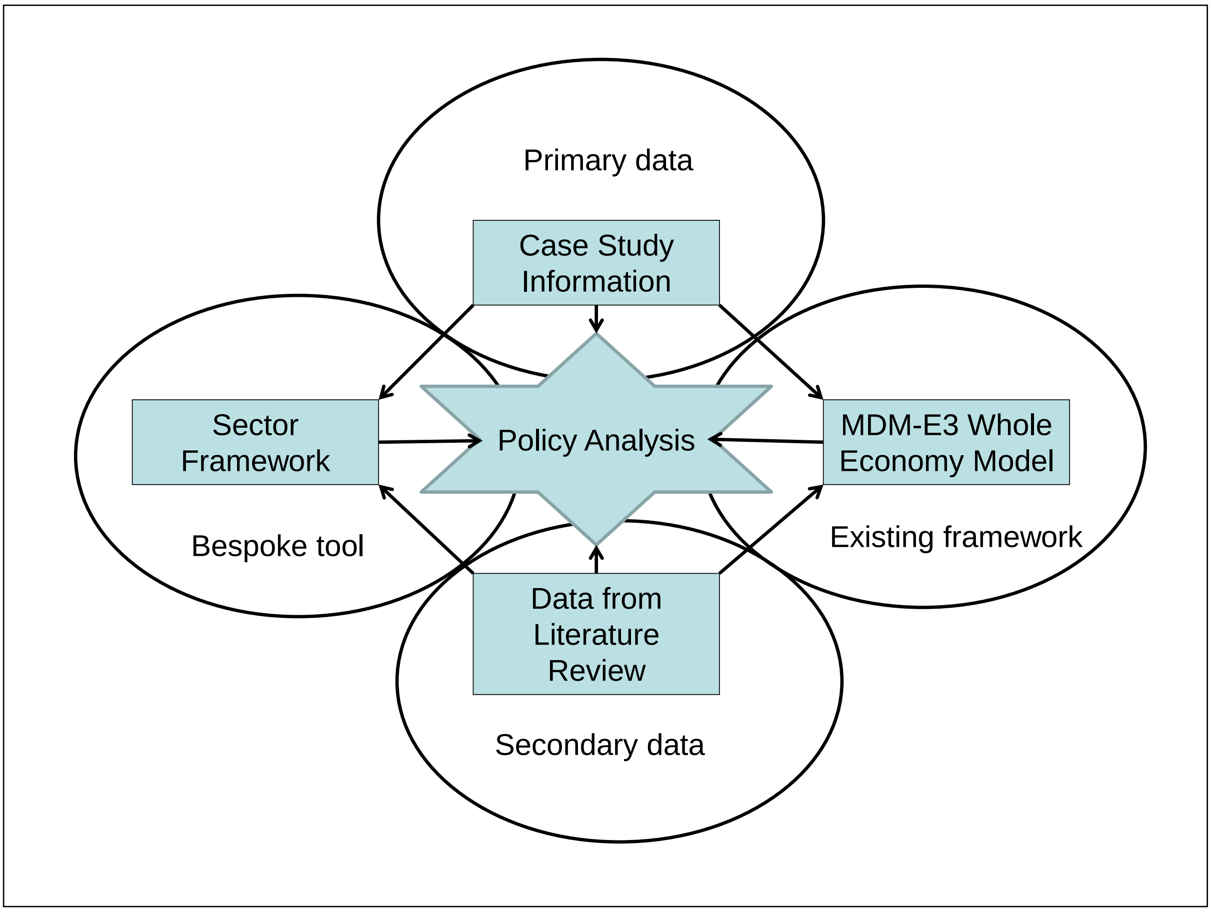

Figure 2.1 Links between the modelling approaches, data collection and analysis

Figure 2.1 illustrates how the data sources and the modelling frameworks have been combined to provide the required policy analysis. In order to meet the research objectives it was necessary to combine several techniques, both qualitative and quantitative. First we needed to collect detailed information from the case studies and the existing literature. This exercise was focussed not only on providing inputs to the modelling approaches but also to determine the drivers behind the resource efficiency and, if possible, to obtain a qualitative understanding of how resource efficiencies might impact on employment and competitiveness at the firm level. Both modelling approaches, explained in more detail below and summarised in Table 2.2, required data on the scale and nature of the no/low cost resource efficiency measures that have been undertaken by companies over recent years. In turn, it was necessary to supplement this data with secondary sources: from the Oakdene Hollins 2007 study we made use of the resource efficiency cost savings estimates. Beyond that, we also made use of ONS and other statistical publications to populate the sector framework (and MDM-E3 model) with economic data at the sector level.

Table 2.2: Characteristics of the two alternative modelling approaches to quantify the impact of quick-win resource-efficiency measures on competitiveness and employment		
Characteristic	**Sector framework**	**Whole-economy model**
Purpose	Analyse the impacts on the sector in which the measures were implemented.	Analyse the impacts of sector-specific measures on the sector and on the wider economy.
Data/evidence incorporated	*Sector case studies*: estimates of resource-efficiency cost savings[12]. *Literature review:* alternative estimates of resource-efficiency cost savings[13]; findings informed the design of the approach. *ONS data* were collated and *econometric analysis* undertaken to identify relationships between: costs and prices; prices and trade/output; and output and employment.	*Sector case studies*: estimates of resource-efficiency cost savings. *Literature review:* alternative estimates of resource-efficiency cost savings[14]; findings informed the design of the approach. Application of *CE's MDM-E3 model* which incorporates.
Method for incorporating resource efficiencies	Only quick-win measures are incorporated. The measures are incorporated in aggregate, as a direct cost saving to the sector.	Only quick-win measures are incorporated. The measures are incorporated as reductions in inputs purchased by the sector (intermediate demand), allocated across those sectors that supply the inputs. The allocation can be varied to best represent the available estimates of resource-efficiency 'cost savings'.
Impacts measured	*For the sector in which the measures were implemented:* Price Imports Exports Output Employment – that resulting from any change in output (NOT changes in employment required to implement the resource-efficiency measures)	*For the sector in which the measures were implemented, for other sectors and for the economy as a whole:* Price Imports Exports Output Employment – that resulting from any change in output (NOT changes in employment required to implement the resource-efficiency measures) Other sector and macroeconomic indicators.
Analysis over time	Static framework. Results indicate the long-term impacts.	Dynamic model. Results indicate the evolving impacts over time.
Strengths	Incorporates sector-specific characteristics. Delivers transparent, user-friendly tool.	Incorporates sector-specific characteristics. Quantifies second-round, economy-wide effects. Dynamic.
Weaknesses	Static. Quantifies only 'first-round' effects for a single sector in isolation.	Uses complex proprietary model.

[12] Case studies did not yield sufficient data/evidence to include in the sector framework: relationship between implementation of resource-efficiency measures and required employment (e.g. green jobs); relationship between costs and prices.

[13] Oakdene & Hollins and Grant Thornton (2007).

[14] Oakdene & Hollins and Grant Thornton (2007).

2.1.2 The Scope of the Modelling Approaches

As indicated above, the impacts of resource efficiency were quantified using two different modelling approaches. The development and testing of the modelling approaches were preceded by more semi-quantitative case study work, which was then used as an input to the modelling. The first modelling approach is the sector framework which identifies relationships between resource efficiency, employment and competitiveness for individual sectors. To understand the wider-economy effects of resource efficiency in a single sector, CE also employed its whole-economy model of the UK, MDM-E3; this is the second approach.

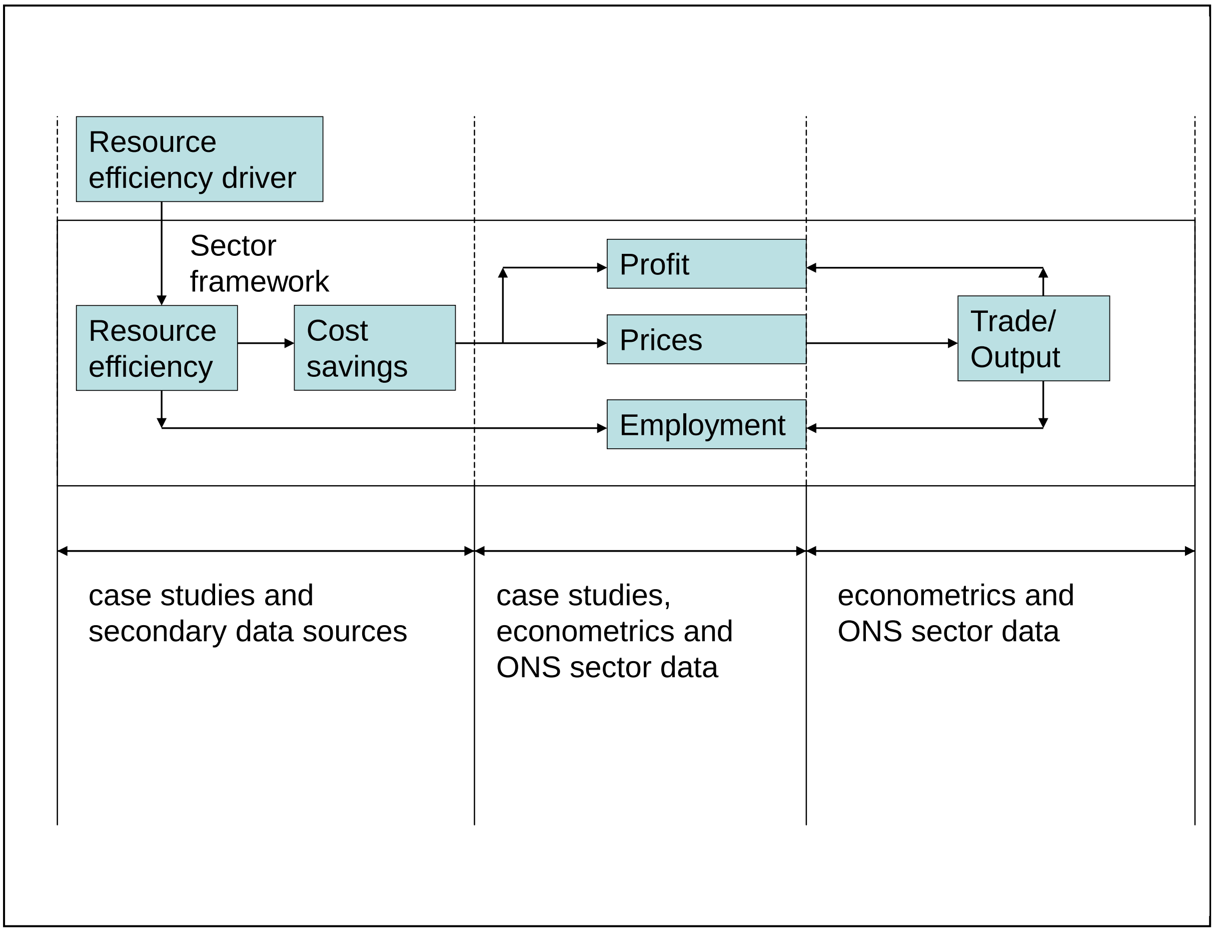

Figure 2.2: Sector Framework Design Overview

Figure 2.2 illustrates the scope of the sector framework, which looks at a single sector in isolation. It sets out how an industry sector might respond to quick-win resource-efficiency measures, and how we have represented competitiveness and employment effects, and makes clear the variables included and the relationships identified and measured. Each variable and relationship in the spreadsheet framework is populated using evidence from a number of alternative sources, namely the case studies, econometric estimation, official data, other data analysis and expert judgement.

In the sector frameworks, which make direct use of the findings from the case studies, we are primarily concerned with:

- the nature of the 'quick-win' resource-efficiency measures (case studies):
  - which resources?

    - what are the cost savings?
    - what were the key drivers underlying the cost savings?
    - are there unintended consequences (positive/negative spillover)?

- the relationship between cost savings and price:
    - are cost savings passed on to consumers through price changes?
    - or, instead, are they retained in the form of larger profits?
    - or, is it some combination of the two, and if so, what is the weighting?

- the relationship between price and trade or output:
    - to what extent do price changes have an impact on industry exports?
    - to what extent do price changes have an impact on industry imports?
    - to what extent do price changes have an impact on domestic demand?
    - overall, then, how is domestic production affected?
    - what can we infer from the above impacts vis-à-vis competitiveness?

- the direct relationship between resource efficiency and employment (case studies):
    - are new recruits required to achieve the resource efficiency?
    - if so, is there a skills gap?

- the indirect relationship between resource efficiency, output and employment:
    - if there is an increase in output, does it create employment?
    - if so, how many jobs are created and are they entirely additional?

In the whole-economy modelling, we are again concerned with the above questions. In this case, the type and magnitude of resource-efficiency cost savings derived from the case studies also forms an input to the modelling. However, we are additionally concerned with:

- the impacts of resource-efficiency measures implemented in one sector on the wider economy:
    - what is the impact of resource efficiency on the resource-supplying industry?
    - what are the whole-economy impacts with regard to prices, competitiveness, output and employment?
    - the dynamics (time-path) of the impact of resource-efficiency savings.

Within our sector framework, we use the case studies to populate and validate much of the data regarding the resource efficiency and cost savings themselves. The case studies also inform us of company level decisions regarding the relationships between cost, prices and profit retention, and the impacts on direct resources and skills. Despite quite a low response rate, we were able to extrapolate these inputs to the sector level, although we are not wholly confident in the results. To give a range of results both the sector frameworks and the whole economy modelling also make use of additional data collected as part of the literature review[15] as a second set of inputs. We did this to provide a back up to the sector case studies as the inputs were not considered robust enough when scaled up to the sector level for further analysis. Finally, the case studies informed the direct employment effects, i.e. those directly related to resource efficiency savings, and more qualitatively to identify the potential skills gaps.

For many of the other relationships within the sector framework, we estimated econometric relationships (as discussed in Section 2.4) using ONS economic data and proxy data from the MDM-E3 model databanks to populate the main variables. We used econometric techniques to estimate the relationships between the cost savings (as a result of resource

[15] Data from Oakdene Hollins and Grant Thornton were used to act as a second set of inputs.

efficiency) and price pass-through (or changes to profit), prices to demand (allowing for the complexity of production changes with regard to trade), the demand impacts on output, and the impact of changes in output on employment.

As discussed in Section 2.5, the whole-economy modelling framework investigates the impacts on the wider economy of resource efficiency measures implemented in a specific sector, and also the dynamic impacts of the resource efficiency savings. Specifically, we used the whole economy modelling to understand how resource efficiency in a sector impacts on other sectors; first the resource supply sectors, second sectors which demand products from our resource saving sectors, and finally the wider economy to interpret the net balance of resource efficiency on employment and competitiveness. This whole economy modelling is carried out using the MDM-E3, CE's econometric input-output model of the UK economy.

2.1.3 What Measures of Competitiveness Are We Assessing?

The Department for Business, Innovation and Skills (BIS) monitors competitiveness and productivity, using a series of indicators, across five broad areas:

- investment;
- innovation;
- skills;
- enterprise; and
- competition.

Although the term 'competitiveness' is widely used in national and international policy debates, the concept has remained elusive. At the national level, competitiveness has been mainly associated with the international trade performance of countries and the ability to achieve sustained economic growth and higher real per capita incomes.

At the firm level, competitiveness is associated with the advantage that a firm has over its competitors, allowing it to generate greater sales or margins and/or retain more customers than its competition. There can be many types of competitive advantage including a firm's cost structure, product offerings, distribution network and customer support. Competitive advantages give a company an edge over its rivals and an ability to generate greater value for the firm and its shareholders.

Table 2.3: Indicators of Competitiveness and Employment

	Firm	Sector	Economy
Competitiveness Indicators	Cost savings, changes to profit	Cost savings, price changes, gross output, gross value added, gross operating surplus (profit), imports and exports	GDP, export volumes, import volumes, price level (PPI, CPI, RPI), and income.
Employment Indicators	Direct job creation as a result of resource efficiency and skills requirements Job re-specification	Overall sector employment change (resource efficiency jobs + output related jobs)	Whole economy employment change (by sector) and changes to wages and salaries
Study Method	Case study	Case studies, sector assessment framework, whole economy modelling	Whole economy modelling

Competitiveness can be analysed using data on market output, trade, costs and profits and investment flows. Thus, for this study it is important that the method is clear on the metrics being used and how they are estimated (see Table 2.2)

There are two main types of competitive advantage: comparative advantage and differential advantage. Comparative advantage, or cost advantage, is a firm's ability to produce a good or service at a lower cost than its competitors, which gives the firm the ability to sell its goods or services at a lower price than its competition or to generate a larger margin on sales. A differential advantage is created when a firm's products or services differ from its competitors and are seen as better than a competitor's products by customers. For this study we are principally concerned with changes in comparative advantage. We recognise that differential advantage will affect employment and competitiveness outcomes but believe that it will not be feasible to measure these in the methods developed, because they are not readily quantifiable. In addition, it seems unlikely that no/low cost resource efficiency savings will lead to firms greatly differentiating their products and services. However, at the firm level, this should be considered when analysing longer term investment-led resource efficiencies. However, the case studies tried to test for information on the nature and impact of differential advantage in a qualitative manner.

There are a wide range of factors that can affect competitive advantage. These include relative availability of resources or skills; the application of technology; economies of scale and (geographical) proximity to the market.

For the purposes of this framework methodology our quantitative focus is on cost and price competitiveness, and the return on investment in the form of profit. While we recognise that resource efficiency is, of course, driven by investment and innovation, as we have previously discussed long-term investment decisions towards resource efficiency is not the focus of this study. Instead, our emphasis is on assessing the impact of quick-win/low-cost measures of resource efficiency on the performance of firms, sectors and the wider economy.

By its very nature, (capacity for) innovation is difficult to measure *ex ante* and there is evidence of heavy path dependence. As a result, it is difficult to establish metrics for innovative capacity, particularly in the case of the quick-wins that this study focuses on. It is of course possible to quantify past innovations, such as internal best practices (e.g. turning out the lights), in terms of the cost savings they generate. Thus, past innovation is covered in this framework, but not the future innovation which might result from resource efficiency.

The sector frameworks we have developed are an attempt to quantify the links between resource-efficiency savings, employment and competitiveness. As stated briefly above, competitiveness in this sense refers to cost/price competitiveness and profitability.

When cutting costs through resource-efficiency savings, a firm essentially has two main options for the cost saving:

- reduce prices charged to consumers; or
- record additional profit (this profit may be used in any number of ways).

A firm is likely to react differently depending on its position within its market and its objective functions (we do not assume profit maximisation). In the first option, lower prices will lead to a domestic demand response and an increase in demand from overseas which, in turn, will lead to an increase in domestic output to meet demand (as an aside this often then requires more resource inputs - essentially the rebound effect[16]). In this instance the firm is more

[16] See Annex D and Section 3.4 Whole-economy Modelling Approach.

competitive in its respective markets. We will attempt to measure the pass-through rate of cost savings to prices, and the ensuing demand response at the sector level. In the second option, the firm returns higher profits to shareholders; this increases the investment prospects of the firm to potential shareholders, which may lead to increased future investment. We will attempt to measure the increased returns to investors, through increased profit at the sector level, as a secondary metric of competitiveness.

To summarise, our metrics of sector competitiveness in this context are:

- domestic prices;
- export prices;
- change in domestic demand;
- change in export demand;
- change in import supply;
- change in net trade;
- profit as measured by gross operating surplus; and
- gross value added.

2.1.4 What Measures of Employment Are We Assessing?

We have identified two linkages between resource efficiency and employment. First, if the firm increases output as a result of increased price competitiveness, then employment is likely to increase in the firm ('greener' rather than 'green' jobs, in the sense that the firm is now more resource efficient). Second, additional jobs could be required to implement resource efficiency in the first place: two examples could be to employ someone to sort waste, or to employ an energy-efficiency manager (so-called 'green' jobs). This might occur outside the business, for example in the waste management sector, an effect which is tested for through the case study evidence.

Our ambition was that this relationship, between the implementation of resource efficiency and the jobs required, would be picked up in the qualitative case study assessment, along with an assessment of the skills requirements and skill level of such 'green' jobs. This would give us another assessment of employment response to resource efficiency but the evidence would be qualitative and not feasible to quantify in the modelling approaches. Moreover, if the resource efficiency measures required sub-contracting to new 'green' start-up companies we might also be able to qualitatively assess the impact on enterprise.

2.2 The Literature Review

Extensive literature review has been undertaken as the first part of this study, looking at the overall economic value of resource efficiency measures. While the majority of literature does link resource efficiency to cost savings, and assume that this directly results in increased competitiveness (which is true depending on how competitiveness is measured), they do not seek to quantify the impact and assess the relationships of cost-price pass through and the impact this has on demand, production (or output) and further onto employment.

Consequently, we have found that both Oakdene Hollins (2009) and WRAP (2009) indicate that resource efficiency or improved environmental performance more broadly should have a positive impact on competitiveness, GVA and profitability. However, a brief review of the literature indicates that this relationship may be less certain. Overall studies reviewed suggest a positive relationship between resource efficiency and competitiveness, but suggests the relationship is rather more complex than first envisaged.

Table 2.4 shows the economic linkages covered (in some way) by each of the main technical studies. Most striking is that none of the papers fully answer the questions required by this study, to assess the impact of known and future resource efficiency on competitiveness and employment. The sector studies focus on interpreting the impact of known resource efficiency on cost savings. While the whole economy approaches focus on the inter-linkages, i.e. the flow to other sectors through intermediate consumption, but often make stylised, and in some cases very simple, assumptions about resource efficiency and its impact on the sector.

Table 2.4: A summary of the economic relationships covered in the technical literature

	Resource efficiency to cost	Cost to price competitiveness	Price to output	Output to employment	Resource efficiency to intermediate consumption
Sector Studies					
CE and AEA (2003)	Yes	No	No	No	No
OakdeneHollins and Grant Thornton (2007)	Yes	No	No	No	No
Urban Mines (2009)	No	No	No	No	No
Rennings and Rammer (2009)	No	No	No[1]	No	No
Whole Economy Studies					
WRAP (2009)	Stylised	Yes[2]	Yes[2]	Yes[2]	Yes[3]
Giljum et al (2007)	Stylised	Yes[2]	Yes[2]	Yes[2]	Yes[3]
Giljum and Polzin (2009)	Stylised	Yes[2]	Yes[2]	Yes[2]	Yes[3]
Stocker et al (2007)	Stylised	Yes[2]	Yes[2]	Yes[2]	Yes[3]

Notes:
1. Rennings and Rammer 2009 do however measure performance, but not the causal relationships leading to improved performance.
2. The models will approach these relationships differently depending on how the assumptions are manipulated and the design of the model. This is a level of detail beyond what is commonly reported.
3. The focus of the whole economy studies tends to be on the flow to other sectors through intermediate consumption.

With regard to the impact on jobs and employment, fundamental economics suggests that in a capital intensive sector, marginal increases in output may not lead to substantial increases in employment. Alternatively, there might simply be a shift in the hours worked on a specific task within the employee's responsibilities, or a change in the skills required for the job. In this case, no quantitative change in employment may actually take place. Modelling at the whole economy or sector level may therefore produce limited results, while the company case studies approach may yield interesting information at the firm level.

2.3 The Approach to the Detailed Sector Case Studies

2.3.1 Overview

Two case studies were agreed with Defra and, as noted earlier, focus on the Food, Drink & Tobacco and Construction sectors. These were developed in order to inform the study's understanding of company behaviour with respect to the adoption of resource efficiency measures. These two sectors were identified from the literature review as offering a high potential for resource efficiency savings. They are also significant contributors to UK gross value added, in particular when compared with other secondary industries. The following table details their contribution to the UK economy.

Table 2.5 Sectoral contribution to UK GVA in 2003	
Sector	**Contribution to UK GVA**
Manufacture of food products, beverages & tobacco	2.2%
Construction	6.2%
Manufacture of chemicals, chemical products, man- made fibres & manufacture of rubber & plastic products	2.4%
Manufacture of machinery & equipment & electrical & optical & transport equipment	4.4%
Manufacture of basic metal & fabricated metal products	1.5%
Source: UK National Statistics (undated): *Change in contribution to gross value added 1992 – 2003*, Available from the **UK National Statistics** Internet site, http://www.statistics.gov.uk/about/methodology_by_theme/inputoutput/downloads/Change_in_GVA_by_industry_2005_edition.xls , accessed on 22nd March 2010	

The case studies gathered information on the following questions in order to provide more qualitative information to inform and verify the outputs of the econometric modelling:

- what measures have been adopted and what are the cost savings that have been achieved?
- when different measures are implemented, what changes do companies choose to make (or are required to make) with respect to their labour force in terms of net numbers, the way in which people work (job descriptions) and the skill mix required?
- when savings are made, what decisions do companies make in respect of how such cost savings are put to use and what effect does this have on their competitive position?

In other words, the case studies help inform the modelling approaches, but also directly answer some of the key policy questions identified in Section 2.1.2, namely:

- the nature of the 'quick-win' resource-efficiency measures:
    - which resources?
    - what are the cost savings?
    - what were the key drivers underlying the cost savings?

- the relationship, albeit qualitative, between cost savings and price:

- the direct relationship between resource efficiency and employment:
    - are new recruits required to achieve the resource efficiency?
    - if so, is there a skills gap?

As some of the information to be collated was not readily accessible in reports or from records kept by agencies active in the resource efficiency support field, a consultation process was launched within the framework of the study involving industry associations, companies, Regional Development Agencies and expert bodies. The examples of specific measures of companies were identified through previous and currently running programmes of the Regional Development Agencies as well as available case study sources. Multiple initiatives (emails, phone-calls and survey) have been launched to establish contact with said companies, information gathered on their results is summarised in Annex G of this report. The information collected throughout the consultation process on the specific measures and results companies have achieved by implementing resource efficiency actions has been incorporated into the case studies.

2.3.2 Consultation with Wider Organisations

To complement the information from the case studies, we carried out consultation with representatives of Regional Development Agencies, National Associations as well as members of Defra's Business Contact Group. The consultation process was undertaken in two phases: Phase I focussed on gathering information regarding the impacts/problems of the currently implemented quick-win measures, and areas where improvements could be made. This phase was undertaken through teleconferences.

A second phase of consultation focused on problem areas - such as the use of cost savings - that have so far remained unanswered. It was undertaken mostly through telephone/conference calls and the use of a short survey that was circulated amongst members of industry associations and other businesses. The reasons for the use of a follow-up survey included the wish to gather further information on employment impacts as well as seeking clarification on previous responses and discussion of particular aspects in more detail. Partly due to time constraints responses have been limited. Table 2.4 provides details of the consultations with a number of national bodies involved in promoting and implementing programmes focussing on resource efficiency. A complete list of the organisations and businesses approached for the consultation can be found under Annex E of this report.

2.3.3 Use of the Literature Review and Case Study Data in the Assessment Framework

For the effects of resource efficiency to be assessed quantitatively, information from the literature review and the case studies had to be translated into inputs that are compatible with the sector framework and the whole-economy modelling approach.

Literature review data, such as that from the Oakdene Hollins and Grant Thornton (2007) study, the data could be inserted directly into the sector framework. For the scenario analysis carried out using MDM-E3, the conversion was somewhat more complicated and involved first converting the cost savings to the 2005 price base used in the model and then calculating, based on intermediate demand flows, the percentage saving. This saving was then shared out to the main production inputs purchased by the sectors selected for analysis.

For the case studies, the data were collected and detailed at the firm level. Where additional information on the size of the firms surveyed was available, the estimated savings were scaled up to the sector level and combined with the aforementioned data on intermediate demand flows to calculate the percentage savings that would be implemented in the model. In some cases, these were shared out to purchases from the major supplying sectors. Where the reasons for the savings seemed similar, the means were taken; in other cases, the implied saving was considered too large to represent a quick win at the sector level and dropped accordingly.

Table 2.6: Consultation Overview			
Contact	**Cost savings**	**Employment**	**Use of savings**
National agencies			
WRAP	Changes regarding the price of construction materials appear immediately as cost cutting measures are introduced. There is a difference between sectors within the FD sector. Savings do not drive prices down	Resource efficiency measures in relation to water use effect job descriptions as additional skill requirements appear	Unknown
NISP	Not available	Directly relatable numbers are not available	Unknown
Regional Agencies			
Yorkshire Forward	Not available	No impact on job creation measured	Unknown
Resource Efficiency/Renewables East	Cost savings from consultations carried out by RE are incorporated into the table	Numbers are not available	Unknown
South West Regional Development Agency	The Ekosgen report on the Envision programme of the SWRDA calculates with a net return of investment of £0.74 and £1.50 for all types of resource efficiency measures implemented	As per the Ekosgen report: there is little evidence in these cases that there is a causal link between resource efficiency actions and job creation. A small number of businesses have reported employing an environmental champion or energy manager as a result or giving a person responsibility for this as part of an existing job	Unknown
The Institute of Environmental Management and Assessment	Not available	The impact of the implemented measures do not directly translate into additional responsibility or into job creation	Savings will be reinvested into the company's operation not necessarily for environmental purposes
Enviros and Aldersgate Group	Not available	Additional requirements might appear in the job description of employees but no job creation is realised through the implementation of the measures companies are more likely to use external consultants	No measurable competitive advantage arises from the measures.

2.4 Sector Frameworks

2.4.1 Sector Framework Overview

The purpose of the sector frameworks is to analyse the linkages between resource efficiency, employment and competitiveness. To do this, we have employed econometric techniques to investigate the structure of the sectors selected for analysis and attempted to reconcile and use this framework with information from the case studies and other third party data sources e.g. the resource-efficiency savings estimates from the Oakdene Hollins and Grant Thornton (2007) study. All of the data used in the study are explained in Annex A for comparison with the whole-economy modelling exercise, much of the sector economic data have been derived from MDM-E3's historical database.

Resource-efficiency savings affect the cost competitiveness and cost structure of a sector and so our first set of econometric investigations looked at the relationship between cost and price: we estimated cost-price pass-through rates. From the impact on prices we then determined the impact on domestic and trade demand by estimating a series of price elasticities. In doing so, we were able to predict likely impacts on net trade, production output and value added. At this point we then related any changes in output to changes in profitability, also accounting for any cost savings retained by firms in the sector. Finally, we estimated the relationship between output and employment, whilst also considering the potential for jobs as a necessary requirement of the resource efficiency from the case studies.

Of these equations and parameter estimates several different economically plausible alternatives were tried and tested. The model with the best fit in terms of R^2 and sensible economic parameters (correct 'sign' and significant at the 10% level) was selected.

From the point of view of these sector frameworks, the purpose of the case studies was to provide the following inputs to the modelling:

1. the size and nature of the resource-efficiency savings (relative to the size of the firm);
2. an indication of the employment requirements required to realise the resource efficiency savings (if any); and
3. validation of the extent to which companies pass cost-savings on to final consumers.

The findings from the case studies (defined at the company/firm level) were scaled up to the sector level for use in the sector frameworks and whole-economy modelling.

For the econometrics part of the framework we estimated the following three relationships at the sector level:

- the relationship between costs and prices;
- the relationships between prices, domestic demand and trade; and
- the relationship between output and price.

These are each considered individually below.

2.4.2 The Relationship Between Cost and Price

The first stage in the sector analysis was to determine the extent of cost-savings pass-through to prices. As discussed in Section 2.1, firms have two options with regard to cost savings: pass them onto the consumer or return the additional profit to investors. At a sector level we expect to see some combination of the two but predominantly, in the long term, we expect to see full cost pass-through. It is worth considering that cost savings from resource efficiencies are not usually sufficient to reduce costs (year-on-year) but instead reduces the yearly increases in cost. If the cost efficiencies were larger, we might expect to see asymmetries in behaviour with sectors potentially retaining more of the cost saving

Our measure of industry cost is unit cost. Unit cost is a composite measure which is made up from the weighted average of the individual input costs. The unit cost series are taken from Cambridge Econometrics' (CE) MDM-E3 input-output model of the UK economy (description of all the data used in the analysis are provided in Annex F. The advantage of using these series is that we are able to capture the complex changes in industry inputs over a period of time, through the input-output structure of the model. The dependent variables are industry output prices; once again data are taken from the MDM-E3 database. These series are based on the implicit chain volume measure (CVM) price deflator and current-price output data.

A number of other variables were included in the price equations we estimated to control for other changes which are not related to costs but might affect price levels; these included competing (import) prices, which are important for sectors, like Food, Drink & Tobacco, where imports account for a large share of industry supply. Other factors, such as the output gap, technological progress and the general price inflation in the economy were also considered.

2.4.3 The Relationship Between Price, Demand and Output

The next step was to determine the relationship between sector output prices and the demand for industry products. We looked at three demand relationships, considering the impact of output prices on:

- domestic demand;
- import demand;
- export demand.

However, for Construction the levels of trade were so low that we focussed solely on the domestic demand equation.

By breaking demand down into these components it was possible to assess not only the impact on domestic and export demand but also the impact of reduced prices on import demand and supply penetration and therefore the competitiveness impacts. In other words, whether domestic production displaces import supply as domestic production becomes relatively cheaper.

An output-price decrease, other things being equal, can be expected to increase total demand for an industry's product through:

- higher domestic demand, where products are highly substitutable from more expensive alternative products or where products are not necessities and therefore consumers start buying them when the price falls sufficiently;
- lower import demand (import substitution), where cheaper domestic product substitutes for imports; and
- higher export demand, where exports are more competitive globally and therefore substitute for more expensive alternatives produced elsewhere.

Consequently, three types of elasticities have been incorporated into the framework:

- the domestic own-price elasticity of demand;
- the export demand own-price elasticity;
- the import demand cross-price elasticity.

The dependent variable in the domestic demand equation is domestic output minus exports plus imports, deflated to obtain a real (constant price) value. It is important to realise that this dependent variable is the domestic demand for the product of the domestic industry (it does not include exports). As such the price elasticities obtained will be the price elasticity of demand for the domestic product (i.e. only demand from domestic consumers and not overseas consumers).

Domestic demand is explained by an income measure, the price of the product and the price of imports of the same product. Economic theory and past experience provide some indication of the nature of possible relationships between the variables and hence the expected sign for the estimated coefficients (elasticities). Classical microeconomic theory suggests that an increase in price will lower product demand. Hence, a negative relationship between price and demand is expected. A positive relationship is expected between demand and national (average) income. This is because as the level of income increases (all other things being equal) demand for a 'typical' product[17] should also increase. Import prices are included in the equations since imports are likely to serve as substitutes for the product of an industry. We expect rising import prices to have a positive impact on domestic demand.

Three alternative measures of income were considered: household expenditure, national income (GDP) and total output from related sectors that are major purchasers of the output of the sectors being analysed. GDP is the preferred measure as it captures the income of the entire economy, which is particularly relevant to both the industries under consideration here. However, in cases where its explanatory power is weak (the variable is statistically insignificant), household expenditure or total output from demanding sectors has been tested as an alternative. If the explanatory power of GDP is weak, this suggests that demand for the industry's products is less connected to overall economic performance and more to economic performance in certain sectors, or to household expenditure directly. Trends in these measures will not necessarily follow trends in the economy as a whole.

The logic behind the import demand specification is similar to that behind the domestic demand equation. In this case, we would expect a fall in import prices to have a positive impact on import demand and a fall in domestic prices to have a negative impact on import demand.

The export demand equation is similar in form to the domestic demand equation. Import prices are used as proxies for the domestic price in foreign countries. The justification for including this in the equation is that domestic production in those countries may represent a substitute for UK exports. We expect world demand (weighted by product) to have an influence on export demand levels for a product.

2.4.4 The Relationships Between Resource Efficiency, Output and Employment

In Section 2.1, we indicated that direct employment in the sector might be affected in one of two ways. First, if the estimated relationships between cost, price and demand suggest

[17] In terms of economic theory, strictly, a *normal good*.

increases in demand for a sector's product, then we might expect supply (output) to match demand, consequently more employment might be required as an input. Second, and more directly, additional employment might be required to realise the initial resource savings.

While we have attempted to econometrically estimate both relationships, a potential problem highlighted in the scoping report was that we might be unable to find a direct link between employment and the implementation of resource-efficiency savings; this was found to be the case in the econometric analysis, where it was not possible (in a time series analysis) to identify a link between sector employment and resource efficiency. Because of this, we believe the case studies are a better guide to understanding the resource-efficiency impacts which directly affect employment. For both sectors we were able to estimate a relationship between output and employment, and in doing so we also tested and accounted for the impact of:

- industrial wages;
- capital investment; and
- technological process.

The findings from the case studies are also the main indicator of how changes in employment might impact on skills.

2.5 Whole-economy Modelling Approach

2.5.1 Overview

This section gives an overview of the use of a detailed computer model of the UK economy to assess the competitiveness effects of resource efficiency. For this we have used CE's energy-environment-economy (E3) model of the UK, MDM-E3.

There are three key advantages in the application of MDM-E3 compared to the sector framework:

1. the model provides estimates of the impact on the industries supplying resources;
2. the model is a complex framework allowing us to interpret the resource efficiency savings in the context of whole-economy interactions;
3. the model is dynamic, allowing us to interpret the evolving impact of the resource efficiency savings over time.

This section is divided into two sub-sections. The first offers a brief overview of the features of the model that are pertinent to this study and the second relates these model characteristics to the analysis that has been undertaken, outlining the method employed.

2.5.2 Features of MDM-E3

MDM-E3, the Multisectoral Dynamic Model, Energy-Environment-Economy, is maintained by CE as a framework for generating forecasts and for conducting scenario analysis to assess the impact of policies on the UK economy and environment. A feature of the model is its high level of disaggregation, distinguishing, among others:

- 41 industries including those identified by Defra for analysis: Food, Drink & Tobacco and Construction;
- 25 types of fuel user, again separately identifying the two industries above; and
- 11 types of energy.

The treatment of energy in MDM-E3 is detailed, comprising a set of sub-models that offer a more comprehensive representation of energy demand that is intended to better reflect the extent to which substitution between different fuels is possible.

The high level of detail in the model makes it suitable for a range of policy analyses because it is possible to target very specific parts of the economy.

Another important characteristic of MDM-E3, for the purposes of this study, is that industries are linked in the model by an input-output table. The input-output relationships track the dependencies between industries in the production of their final good or service. Thus, an increase in output from the Food, Drink & Tobacco industry, say, would have to be met by an increase in supply of inputs from Agriculture. The flows of production between industries, one industry's output being used as another's input, are termed intermediate demand.

The other main input to production is labour. MDM-E3 contains endogenous treatments of both employment and wages by industry. Wages are determined principally by the prices of final goods in the economy, through a wage-bargaining model. The resulting labour costs (and, implicitly, the labour cost relative to the material costs) are among the determinants of industrial labour demands, which are also influenced, among other things, by the required level of industry output.

The price of final production in the model is determined as a function of costs, allowing for a mark-up that represents each industry's profit margin. The price is moderated by the price of competing goods and services from overseas, i.e. competition.

MDM-E3's representation of the productive structure of the UK in this manner is a key aspect of the analysis that has been undertaken. It is a demand-led model and the underlying assumption is that production (and imports) adjusts to meet the demand for final production. The components of final demand are all represented in the model, and are all further disaggregated:

- household expenditure (51 categories);
- investment expenditure (27 types of investment);
- government expenditure (five categories);
- export demand (by the 41 industries); and
- import demand (by the 41 industries).

The levels of demand for each are determined principally by activity (income/output) and prices (described above). The exception is government demand, for which assumptions are made on future spending.

As an example of the circularity of flows in the model (and indeed the UK economy): demand for industry output generates intermediate demand for other industries' output as well as demand for labour. Demand for labour affects wages (and thus prices) and, in turn, incomes which impact on household expenditure. A change in the economy (e.g. through a policy) can thus be seen to lead to potentially much wider economic impacts than the direct effect initially observed.

2.5.3 Analysing the Impacts of Resource Efficiency in MDM-E3

The method for analysing the economic impacts on resource efficiency using MDM-E3 involves modifying the nature of the industry relationships (the intermediate demands) between the two sectors to be studied and their main suppliers. Changes in the composition of these industries' purchases of inputs, per unit of output, will have wider impacts. The impacts of most relevance are:

- industry prices:
    - changes in the production process will alter the industries' cost structures; some of this change can be expected to be passed on to final prices,
    - there may be indirect impacts on wages through changes in final prices;

- employment:
    - changes in wages will affect income which will in turn affect demand and thus industry output,
    - there may be substitution effects as a result of changes to the utilisation of other industry outputs.

It will of course be necessary to consider other indicators produced by the model in explaining the above effects.

As already mentioned, the two sectors identified by Defra for analysis are also distinguished in MDM-E3's industry classification. Moreover, the model identifies a number of other sectors that supply inputs to production (to meet the aforementioned intermediate demand) that will be of use in this study:

- energy: coal, oil & gas, manufactured fuels (petroleum products), electricity supply and gas supply;
- water: water supply
- waste: miscellaneous services (waste treatment and disposal)

Regarding materials, the two sectors purchase inputs from different sectors. The main sectors of interest here will be:

- food, drink & tobacco:
    - agriculture
    - distribution (wholesale of agricultural raw materials)
    - rubber and plastics (plastic packaging)
- construction:
    - wood & paper (carpentry, joinery etc)
    - rubber & plastics (plastic fittings)
    - non-metallic mineral products (cement, lime, plaster and bricks)
    - metal goods (various metal structures and fixings)
    - distribution (builders' merchants)

The method for modelling changes in resource efficiency consists of modifying inter-industry demands for resources. This requires the translation of the resource-efficiency measures identified in the case studies into sets of model inputs; the conversion must identify how much demand from Non-Metallic Mineral Products, say, which is a broad sector encompassing a wide range of construction materials, has been reduced by each measure, in monetary terms. Such an exercise is required because we are unable to distinguish individual products or production processes in the model. As a result, there is likely to be some uncertainty surrounding these input assumptions, particularly for what might be regarded as a 'soft' measure that may be more regulatory in nature. Because of this, it was decided to model two scenario variants for each sector: one using the findings from the Oakdene Hollins and Grant Thornton (2007) study; and one using the case study results. The scenarios we modelled are as follows:

- Scenario 1a: Food, Drink & Tobacco, Oakdene Hollins and Grant Thornton;
    - this scenario analyses the resource-efficiency savings calculated for the Food, Drink & Tobacco industry, based on the earlier work by Oakdene Hollins and Grant Thornton (2007)
- Scenario 1b: Food, Drink & Tobacco, Case Studies;
    - in this scenario, Food, Drink & Tobacco is analysed using savings calculated from the case study findings obtained in this project
- Scenario 2a: Construction, Oakdene Hollins and Grant Thornton; and
    - this scenario analyses the resource-efficiency savings calculated for the Construction industry, based on the earlier work by Oakdene Hollins and Grant Thornton (2007)
- Scenario 2b: Construction, Case Studies.
    - in this scenario, Construction is analysed using savings calculated from the case study findings obtained in this project

In the case of energy efficiency, it was originally planned to model changes in energy consumption through the energy component of MDM-E3. This part of the model projects energy demand by fuel user and fuel type and the results feed back to the economy through changes in intermediate demand. However, the final inputs to the scenario analysis were insufficiently detailed to model this and the final method follows the one detailed above.

In three of the four aspects of resource efficiency identified, the model inputs can be interpreted in a relatively straightforward manner: resource efficiency leads to lower consumption, per unit of output produced, of energy, water and materials. In the case of waste, however, the interpretation is more subtle because waste is not consumed, it is generated in production. Analysis of the case study results and those from the Oakdene Hollins and Grant Thornton (2007) study suggested that many of these efficiency gains were best reflected as reductions in purchases of inputs rather than reductions in waste generation.

A further consideration relating to modelling changes in waste generation is that a reduction, for example, in resource consumption (energy, water or materials) may also in itself lead to a reduction in waste. For example, lower water consumption by industry may lead to lower wastewater at the end of the production process. For simplicity, this effect was assumed to be too small and not included.

In the comparison of results between the modelling approaches, we used the year 2015 from the whole economy modelling. This year was selected because it was sufficiently after the implementation of the resource efficiency measures to compare the long term impact (which is what we see from the sector framework) and not so far in the future that it lacked credibility and policy relevance.

The analysis precludes the possibility of opportunities arising from the development of ‘green’ businesses and jobs associated with a more resource-efficient economy that may themselves lead to new jobs. The principal obstacle to quantifying such opportunities is attributed to the absence of, and difficulty in collecting, such data.

Furthermore, the analysis undertaken in the whole-economy approach focuses on the impacts of adopting resource-efficiency measures in the two sectors selected for the study only. Other sectors do respond to the changes in demand for production inputs in the model but no explicit efficiency measures are modelled in other sectors; the impact of economy-wide measures has not been assessed.

2.6 Limitations and Assumptions

2.6.1 Summary

The objective of this study has been to identify and test a method by which the effect of resource-efficiency measures implemented by businesses on employment and competition can be determined. Our approach has sought to make the best use of a number of methods and secondary estimates of data. The alternative methods have their own strengths and limitations, as discussed below.

First, the sector framework is necessarily limited to analysing the first round direct effects within a sector. However, we were highly aware of this at the design stage and proposed that we also model the resource efficiency savings in CE's whole economy model of the UK, MDM-E3. Although a number of the potential limitations have been reduced by employing two different modelling methods there are still limitations associated with both and these are discussed in sections 2.6.3 and 2.6.4.

Second, the case studies, (the results of which are applied to both modelling approaches) while developing interesting company level conclusions on the impact of resource efficiency, did not return as much information as we would have preferred for the sector level and whole-economy modelling. The solution to this was to also make use of estimates of cost savings from previous studies and compare the model results with those that used the case-study estimates. However, had the scope of the project permitted, a full survey covering a larger number of the companies in a sector would have produced a greater set of estimates to test in the modelling approaches. However, to improve the quality of data, it would also be necessary to conduct a full scale interview with each organisation so as to infer the full set of company level data required, particularly picking up on whether 'green' jobs were required to implement the resource efficiency measures and making sure that the size of the company was given in revenue terms throughout. There are few suitable alternatives to this approach to data gathering, particularly because of the detail of information required to inform any study and modelling approach. For example, using a modelling approach it would be possible to construct a counterfactual projection and then determine the level of resource efficiency savings which have been realised, but the results would be highly contentious; it would not be clear what was being captured in the results in terms of the type of efficiency saving, the cause (driver) of the efficiency saving, or to capture any qualitative information about the impacts this has had on the company.

By design, we have also limited ourselves to focusing on no/low cost resource efficiency savings. As a result, our estimates of resource-efficiency savings are relatively small. Furthermore, because we have not concerned ourselves with resource-efficiency savings which require considerable investment we have not developed the frameworks to consider the impact of associated costs, eg increased investment, which will be of particular importance to some indicators of competitiveness which are not the focus of this study, like innovation.

2.6.2 Limitations of the Case Studies

The main limitation of the case studies was that companies were not always able to give the answers required to inform the two modelling approaches beyond giving some indication of the scale of resource-efficiency savings they had recently observed and an indication of which resources were reduced. Further still, respondents found it difficult to differentiate between no/low cost resource-efficiency savings and those which required a substantial up-front investment cost.

Specifically we have encountered several problems that prove to limit the extent of data and information the study can provide.

1. Due to the nature of the industry and the lack of readily available information - case studies on businesses within the Tobacco industry have not been included in the study.

2. While information regarding the measures and their implementation costs has been achieved directly through consultations and a literature review; there has been a lack of access to data regarding how companies utilise the savings they have made through implementing resource efficiency measures.

In the event that information regarding any specific jobs that may be created through the implementation of “quick-wins” is limited, our approach was extended to contacting a number of individual companies directly. We unfortunately received only limited responses on this question.

Data availability has been a particular limitation for this study. This could perhaps be due to the issue of consultation fatigue, with businesses continually being asked for their opinions and ideas and not having the time or inclination to fill in what they may see as yet another survey.

Confidentiality is a second issue which affected data availability. Several consultees, in particular those from the Regional Development Agencies, stated that data on resource efficiency measures and cost savings had been collected. However, these data were not made available for this study since they were not in a suitable format (in many cases it would have been possible to identify individual companies) and such organisations did not have the time to process the data.

The data which were collected were limited in terms of how they could be disaggregated. For example, it was often not possible to break down the information gained from construction companies, since savings were reported at the project level. Consequently, it is hard to attribute benefits to a single measure or even to combinations of quick-win measures. This issue subsequently makes the identification of the impacts on employment and competition difficult. Since many quick-win measures are implemented as part of a package, it is hard for companies to make any direct links between a particular resource efficiency measure and impacts on the number of employees, their job descriptions, and the company’s competitive position. It should additionally be noted that given the current economic climate, any monetary gains from resource efficiency measures may be used to help companies balance their books, rather than for investment in new employees or reducing prices. The findings given here may therefore only be applicable when economic conditions are harsh. This issue is likely to be especially relevant for the construction industry, since the sector has been particularly badly affected by the recent recession. Although the food and drink sector has less direct exposure, it too will have been detrimentally affected by changes in consumer spending. It is therefore necessary to acknowledge that the timing of this study could be affecting the impacts of resource efficiency measures in terms of the cost savings which could be made and their knock-on effects.

2.6.3 Limitations of the Sector Framework

The purpose of the sector framework is to provide a relatively simple tool, applicable to any sector, which links the impacts of resource-efficiency cost savings to employment and competitiveness within the sector. The framework is programmed in Excel and is relatively straightforward for a user to operate to investigate alternative scenarios of resource-efficiency savings. In Chapter 3 we explained that the framework would be informed by both the information from the case studies and an econometric assessment of the sector. The purpose of the econometric assessment was to provide an understanding of the economic structure of the sector, so as to estimate the impact of resource efficiency on our measures of competitiveness and employment. From the case study data, we had specifically hoped to inform the relationship between resource efficiency and the so-called 'green jobs' which would be directly linked to implementing the resource efficiencies we had identified. However, of the 28 responses we were able to obtain, only one reported that jobs were required to implement the resource efficiencies. As the results suggest, we believe this to be linked to the nature and scale of the no/low-cost resource efficiency savings which were the focus of this study, as the relatively small cost savings identified were not substantial enough to require 'green' jobs.

Another intention of the case study was to validate the econometric findings on cost pass-through. However, we find the case studies and model results contradict one another. This is perhaps not unsurprising because the econometric parameters describe the relationship between cost and price for the sector as a whole, the resource-efficiency savings are not large enough to reduce sector costs year-on-year and only serve to reduce the size of the cost increase. However, for an individual company this is not necessarily true, the resource-efficiency savings might be large enough to reduce overall costs year-on-year. However, it is not clear whether the inferences from the case studies are robust enough to draw this conclusion. For the resource efficiencies assessed in the sector framework we make the assumption that our sector estimates are suitable because the resource efficiencies are a relatively small proportion of cost, but this assumption would need testing against larger resource efficiency savings.

In any econometric equation it is difficult to assess whether we observe causal relationships or whether we are in fact simply observing two, or more, independent but correlated series: the issue of spurious regression. However, the results we observe do underpin our *a priori* economic theory, which leads us to believe, qualitatively, that they are valid approximations of the underlying system.

Many of the other limitations of the sector framework are dealt with by the whole economy modelling approach. These limitations are:

- the sector framework is a comparative static model and ignores the second-round effects, including:
  - the impact on the economy-wide price level of changes to sector prices
  - the responsiveness of import price to changes in domestic prices
  - the secondary flows of income;
- the impact of resource efficiency on intermediate demand is also ignored by the sector framework, this impacts on supply industries' GVA, employment, incomes and back to domestic demand;
- the complexities and dynamics of the labour market.

However, it is entirely for these reasons that we employed two different modelling methods to understand the relationships between resource efficiency and competitiveness.

2.6.4 Limitations of the Whole-economy Modelling Approach

The whole-economy modelling approach applied CE's MDM-E3 model of the UK to assess the macroeconomic impacts of resource-efficiency savings beyond the sectors that actually implement them. This involved translating the savings identified in the Oakdene Hollins and Grant Thornton (2007) study and the case studies undertaken as part of this project into sets of inputs defining resource savings at the sector level in MDM-E3. We thus modified the nature of purchases made by Food, Drink & Tobacco and Construction from sectors further up their respective supply chains.

A clear limitation of the modelling approach is the manner in which company-level savings have been scaled up to the sector level and the attribution of these savings to other sectors' production of inputs.

The underlying assumption when scaling up the company-level savings to the sector level is that all companies that comprise that sector, regardless of their size or the specific characteristics of their product or production process, can undertake the same resource-efficiency measure and will realise a similar level of cost savings as a result. This represents a mismatch between the level of aggregation in the model (41 quite broad sectors) and the company-level detail of the case studies. While we acknowledge this weakness, in the absence of more detail on the firms, in order to develop a more detailed picture of the savings across the sector as a whole, there is little more that can be done for the current study. The results should thus be interpreted as conditional on the assumptions made about the resource-efficiency measures undertaken.

The issue of scale is further compounded by the fact that the savings focused on in this project are quick wins and are, in general, small in value relative to the overall size of the sectors. This can be seen in the scale of the results when presented in terms of percentage differences: they are generally less than 1%, the indirect impacts often much less. These small changes also lead to similarly small changes back up the supply chain when compared to the size of the supplying industries. This issue of scale is not easily addressed due to a lack of data at a sufficient level of disaggregation to model a more detailed supply chain.

Another issue regarding the nature of the resource-efficiency measures modelled is the way in which they have been attributed to sectors further up the supply chain. For example, in most cases, details of the type of material saving made was not available. In such cases, the assumption was made that the savings were spread across the main sources of material supplies according to their share of intermediate demand. Again, in the absence of further detail on the savings, this seemed a reasonable assumption to make. The inability to obtain further detail on the savings also highlighted the difficulties in identifying waste-reduction measures that could be readily attributed to reductions in waste disposal/treatment costs. In most cases, the savings appeared to be better modelled as reductions in material consumption through more efficient use of these inputs. The issue of waste thus goes largely unaddressed in the modelling and is an area that would be useful as a topic of future analysis.

It is also important to note that the results presented in this report are from one particular class of economic model: a large-scale, econometric, input-output model. The results are themselves conditional on the underlying premises of the model and these are potentially very different to other classes of models, perhaps most notably Computable General Equilibrium (CGE) models. The implication is that the same resource savings analysed in a different model could produce potentially different results, based on differences in the underlying assumptions and analytical framework. As long as the assumptions and frameworks are clear (further information on MDM-E3 can be found in Annex F), to understand the reasons for the differences, we see no particular problem with this.

A particular criticism of econometric models, of which MDM-E3 is one, is that the behavioural relationships are estimated on past data and may not necessarily be useful in the analysis of policies that may potentially invalidate the estimated relationships themselves, because agents' behaviour may change under the new policy regime. This is the essence of the 'Lucas Critique' and is a criticism we accept: it is difficult, if not impossible, to deny that policies that may invalidate a model's equations render the model results misleading. In practice, the literature suggests that assessing the extent to which the Lucas Critique actually hold is empirically challenging; while of clear theoretical importance, its relevance in practice has so far been difficult to identify.

In any case, as already noted, the changes modelled in this analysis are small, as are the impacts. For such small changes, it is not immediately obvious why agents might substantially alter their behaviour in response to the savings modelled and the savings lead to impacts on variables such as price, output and employment that are well within the range of historically-observed values for these variables.

3 Results

3.1 Summary of Results

This section presents an overview of the results; more detail on the modelling approaches can be found in Sections 3.3 (for the sector frameworks) and 3.4 (for the whole-economy modelling).

The resource efficiencies identified in our case studies are fairly modest as are those identified by Oakdene Hollins (2007). The Oakdene Hollins estimates of resource-efficiency savings from no/low-cost measures are £254m for Construction and £939m for Food, Drink & Tobacco in 2005 prices. These savings are relatively modest in percentage terms (0.2% of Construction costs and 2.4% of Food, Drink & Tobacco costs). However, this is not to say that the measures are not in any way beneficial and they amount to £254m for Construction and £939m for Food, Drink & Tobacco. As we note later in this chapter, straight monetary valuation of the savings is not necessarily the most appropriate metric by which the savings should be evaluated. Moreover, it seems likely that the classification of no/low-cost measures will change over time; new measures may become low cost, possibly in part because of previously-implemented measures. The savings are also reported for a particular period in the past; additional savings may have been implemented since then.

The sector estimates for resource efficiency obtained from the case studies are not as robust as the Oakdene Hollins findings because the sample size is substantially smaller. As such the results should only be considered as indicative and are reported here as an alternative set of inputs to the sector frameworks and the whole-economy modelling to help illustrate the range of possible results.

Table 3.1 shows the total resource-efficiency cost savings used in the following analysis, expressed in both levels and as a percentage of total cost. This table summarises the inputs to the four scenarios that have been analysed in both the sector frameworks and the whole-economy modelling approaches; the results of each are detailed later in this section. The scenarios are:

- Scenario 1a: Food, Drink & Tobacco, Oakdene Hollins and Grant Thornton:
  - In this scenario analyses the resource-efficiency savings calculated for the Food, Drink & Tobacco industry, based on the earlier work by Oakdene Hollins and Grant Thornton (2007);

- Scenario 1b: Food, Drink & Tobacco, Case Studies:
  - in this scenario, Food, Drink & Tobacco is analysed using savings calculated from the case study findings obtained in this project;

- Scenario 2a: Construction, Oakdene Hollins and Grant Thornton: and
  - In this scenario analyses the resource-efficiency savings calculated for the Construction industry, based on the earlier work by Oakdene Hollins and Grant Thornton (2007);

- Scenario 2b: Construction, Case Studies:
  - in this scenario, Construction is analysed using savings calculated from the case study findings obtained in this project.

Table 3.1: Resource Efficiency Savings				
	Oakdene Hollins		Case Studies	
	£m 2005	% cost	£m 2005	% cost
Construction	254	0.24	1058	1.02
Food, Drink & Tobacco	939	2.36	341	0.87

The summary results show the impact of the resource-efficiency savings to be modest in both the sector frameworks and the whole-economy modelling in MDM-E3. Because the results from the sector frameworks are effectively long-term impacts[18] and thus do not show the dynamic responses, for comparison purposes, in the whole-economy MDM-E3 modelling exercise we will take the 2015 differences from the baseline to assess the long-term impact of the resource-efficiency measures.

The results for each sector differ between the sector frameworks and the whole-economy modelling. This is perhaps not surprising given the differences in design, scope and complexity of the two approaches. Table 3.2 shows the impact of the sets of resource efficiencies identified in the two sectors on GVA (as a summary indicator of competitiveness) and employment from both the sector frameworks and the whole-economy modelling.

Table 3.2: Impact of Resource Efficiency Savings (%)					
	WE/SF	Cost Saving	GVA impact	Net Trade	Employment
Oakdene Hollins					
Construction (S2a)	WE	0.24	0.47	n/a	-0.15
Construction (S2a)	SF	0.24	0.06	n/a	0.06
Food, Drink & Tobacco (S1a)	WE	2.36	5.21	0.56	-0.49
Food, Drink & Tobacco (S1a)	SF	2.36	1.65	2.86	1.42
Case Studies					
Construction (S2b)	WE	1.02	1.8	n/a	-0.65
Construction (S2b)	SF	1.02	0.23	n/a	0.24
Food, Drink & Tobacco (S1b)	WE	0.87	1.74	0.17	-0.27
Food, Drink & Tobacco (S2b)	SF	0.87	0.62	1.14	0.52
Note(s): WE = whole economy modelling, SF = sector framework. S1a – Food, Drink & Tobacco, Oakdene Hollins S1b – Food, Drink & Tobacco, Case Studies S2a – Construction, Oakdene Hollins S2b – Construction, Case Studies					

For Food, Drink & Tobacco both sets of analyses give broadly similar results with regard to competitiveness effects, for two reasons. First, the pass-through to price is just less than 100% of the change in costs and so a small proportion of the resource-efficiency savings is retained as higher profit and, consequently, sector GVA is higher. Second, in response to

[18] In this case long term represents the period of time it takes for the economy to return to a steady state after the initial shock. The long term is therefore difficult to quantify but given the size of the shocks we would expect this to be between five to ten years.

lower (domestic) prices there is a modest demand response which increases domestic demand and shifts the trade balance in favour of domestic production.

Compared to the sector framework analysis, in the whole-economy modelling undertaken in MDM-E3 feedbacks from the rest of the economy mitigate some of the impact on demand of lower prices of Food, Drink & Tobacco products because the cost savings lead to lower price inflation. The relative sector price reduction is therefore dampened when considered against other UK goods.

When the cost-saving estimates from the case studies were analysed in the whole-economy approach in MDM-E3, the results were dominated by a reduction in intra-industry demand: some of the resource-efficiency savings from the case studies implied a reduction in demand for inputs of primary food products in the manufacture of final Food, Drink & Tobacco products. The result was an overall reduction in Food, Drink and Tobacco sector output that outweighed the increase in demand from lower prices.

Using the Oakdene Hollins inputs we see a more intuitive increase in output from Food, Drink & Tobacco in both the sector framework and the whole-economy modelling. However, the results for employment varied. In MDM-E3, the additional output was met by an increase in the average hours worked in the sector rather than more workers hired. This result is driven by an econometrically-estimated relationship intended to capture the effect of required increases in economic production on the labour market: to some extent, and especially in the short term, employers may demand higher working hours from employees rather than higher employment. Interestingly, this effect is not temporary and persists over the period modelled and as a result of increased labour productivity we eventually see a decrease in employment (compared to baseline).

For the Construction sector the differences in the results between the sector framework and the whole-economy modelling are more noticeable still. The first round of impacts is similar: none of the resource-efficiency savings are retained as profit, as a result of almost identical rates of cost pass-through (100%). However, that is where the similarity ends. In the whole-economy modelling, the impact of reducing resource inputs leads to a sizeable reduction in intermediate demand, which in turn leads to reductions in output from a number of sectors that supply inputs to Construction. This leads to a reduction in value added and incomes, which more than offsets the increases in demand for Construction brought about by lower prices, in marked contrast to the sector-framework results. This effect dominates the price effect for two reasons: the Construction sector relies on a large supply chain and so the multiplier effects as a result of a reduction in intermediate demand are substantial; and because the price elasticity of demand for the Construction sector is quite small as it is driven principally by economy-wide growth and investment.

In summary, the evidence on the relationship between resource efficiency and employment and competitiveness is mixed, although it is important to note that the inputs to the modelling (the estimated cost savings at the sector level) are small and the consequent economic effects similarly small. The first-round comparative static effects (obtained from the sector frameworks) would seem to point to overall gains, albeit modest, in both competitiveness (as measured by increases in GVA, profit and trade) and employment. The impacts on the whole economy (using MDM-E3), which account for inter-industry linkages and thus embody a more complex system for analysis, suggest that the policy implications are not so clear-cut. The whole-economy modelling results suggest that the first-round effects can potentially be outweighed by secondary effects (e.g. reduced demand for the supply-chain sectors, and the associated reduction in employment and incomes, and also the economy-wide impacts of changes in prices), implying that income effects can be substantially larger than the price effects that result directly from the resource-efficiency savings. We also find evidence, in the case of Food, Drink & Tobacco, that the higher output required to meet higher demand may lead to an increase in demand for labour inputs being met not by additional employment, but higher per-worker output.

Although resource-efficiency savings are beneficial in their own right, given the constraints on resources that have been widely anticipated, our findings suggest that resource-efficiency measures might not have the all-round positive impact that might be anticipated *a priori*. In fact, the impact of resource efficiency on the economy is likely to vary considerably by sector and the characteristics of that sector, namely:

- the positioning of the industry with regard to final product supply chains:
    - resource savings in a highly-connected sector with a long supply chain, like Construction, can transmit larger changes in demand through UK industry than a relatively less-connected sector, such as Food, Drink & Tobacco, which has a much shorter supply chain;

- the import intensity of the resources whose demand is reduced:
    - the economic impacts arising from lower demand for imported inputs to production will be felt overseas, in the economies of trading partners; multiplier effects in the UK will be muted. The extent to which sectors are supplied by overseas suppliers affects the whole-economy impact;

- the type of resource efficiencies, as there may be intra-industry feedbacks:
    - at the level of sectoral disaggregation in the approaches reported here, sectors often source inputs from 'themselves' ie an input to the production of one unit of Food, Drink & Tobacco product (eg bread production) may have been supplied by another Food, Drink & Tobacco firm (eg flour). In such a case (detailed below in the whole-economy modelling), resource-efficiency savings have two direct demand effects, on both final and intermediate demand; both affect a sector's gross output;

- the price elasticities of demand (and trade demand):
    - the more responsive demand is to prices, the greater the demand and consequent economic effects of lower prices;

- the degree of influence of the business cycle on demand for the sector:
    - that is, the extent to which the economic performance of the UK as a whole affects demand. This is perhaps most clearly seen in the case of Construction, which is a sector that depends greatly on investment expenditure;

- the cost pass-through rate:
    - the size of a sector's supply chain determines the 'upstream' impact, while the extent to which a sector tends to pass savings on through lower prices (as opposed to higher retained profit) is key in determining the 'downstream' impact;

- labour market interactions influenced by the business cycle:
    - the extent to which higher production is met by higher employment rather than a requirement for more hours worked per worker.

Characteristics of the two sectors analysed for this project, with respect to those listed above, are outlined in Table 3.3.

Table 3.3: Characteristics of the Sectors Analysed		
	Food, Drink & Tobacco	**Construction**
Length of supply chain	Concentrated	Extensive
Import intensity of inputs	Medium	Low
Extent of intra-industry trade	Potentially high	Low
Price elasticities of demand	Medium	Low
Responsiveness of production to business cycle	Low	High
Cost pass-through	Medium	High
Nature of labour response to business cycle	Some tendency for greater output per worker	Largely higher employment

3.2 Key Results from the Case Studies

3.2.1 Key Findings

The case studies essentially focused on the following aspects:

- the types of quick-win measures that have been implemented;
- the level of cost savings achieved;
- the changes in both the nature of employment as well as the number of jobs that may result from implementing resource-efficiency measures; and
- the changes in the competitive position of companies as a result of any cost savings made due to the implementation of resource-efficiency measures.

The range of potential short-term resource efficiency measures which may be implemented in order to achieve cost savings had been identified for both sectors and can be found under Annex C-D The measures are categorised into four groups depending on whether they relate to energy, material, waste or water. From these measures, a range of quick-win categories can be further detailed under specific actions such as:

- establishing key performance indicators;
- recycling, re-use schemes;
- mass balance;
- training of employees;
- regular preventive maintenance;
- regular audits; and
- monitoring of processes/use.

Examples included in the case studies under Annex C-D indicate that the identification of the main resource consuming production processes and their demand for inputs is one of the focal points in implementing appropriate quick-win practices. Furthermore, the case study scenarios suggest that low cost measures, such as integrated waste management practices and a focus on recycling, can substantially contribute to the greening of an operation (e.g. case study examples had shown that low cost waste management practices and the recycling, reusing of materials can reduce the amount waste sent to landfill sites). At the same time measures raising staff awareness, through employee training or identification of processes where improvements could be made can also boost cost savings.

Table 3.4 lists actual examples of measures which have been implemented by companies and for which we were able to obtain further information regarding the levels of savings accruing to companies. In some cases details on whether the measures have produced new jobs has been available, as well as much more limited information on how savings arising from implementing resource efficiency measures have been used.

A common characteristic of both industries is that the implemented quick-win resource efficiency measures most often reflect company policy regarding environmental awareness. As a result, the same measures are expected to be applied by contractors and suppliers. In other words measures implemented throughout or across a supply chain are often regarded as more efficient in terms of meeting business targets and strategies. For example, if waste is being segregated for recycling, it may be worthwhile considering whether any materials can be re-used on site, thus decreasing input costs as well as saving transport miles.

Some of the quick-win measures have immediate effects, e.g. a water efficiency campaign amongst employees together with small scale investments such as the purchase of meters can contribute to significant cost reductions. Other examples prove that cost reductions can appear on more than one level; for example energy efficiency measures such as insulation, draft proofing of doors, emplacement of thermostats can contribute to energy savings as well as CO_2 reductions, which can not only directly cut costs for companies but through the Climate Change Levy can also mean tax reductions.

A number of issues regarding the achievement of economically beneficial and environmentally positive impact through implementing resource efficiency measures were also raised during the consultation process and the case studies. These issues can be grouped under three main headings:

- business solutions (solving production related/technical problems or challenges);
- capacity (identifying processes where improvements can be made); and
- strategy (improving competitiveness, enhancing reputation, CSR etc).

Business solutions related to the cost effectiveness of production are often incentives for businesses to implement low-cost resource efficiency measures. These measures can be integrated into production mechanisms to support other technological improvements made to increase productivity or efficiency. One of the first and most important steps in implementing the appropriate resource efficiency measures is the identification and monitoring of the precise amount of resources specific processes need and/or use. This enables manufacturers to establish the whether there is an excess of resource use and to identify the amount of reductions necessary to achieve their targets. Apart from evident cost saving and productivity enhancing implications, corporate image and corporate social responsibility are also a factor in the implementation of resource efficiency measures. As businesses recognize the importance of an environmentally conscious image they may be keen to develop business strategies which incorporate resource efficiency measures. Consumer awareness of environmental issues may ultimately give those companies with environmental policies a competitive advantage.

Overall it can be seen that a range of resource efficiency measures are being implemented by both sectors, with many of these resulting in considerable cost savings. However, it is difficult to determine the actual amount of savings directly related to a particular measure over a time period (e.g. savings per year); as for example, in the Construction sector many of the savings are reported on a project by project basis. This means that data on cost savings are not strictly comparable since each project is likely to be of a different value and duration, particularly where smaller firms are being compared with larger companies.

Table 3.4: Measures Identified from Case Studies as Occurring Across More than One Company				
Category	**Measure**	**Group**	**Food and Drink**	**Construction**
Waste	Recycling products into constituent parts, reducing the number of waste contractors	Recycling, re-use schemes	✓	✓
Waste	Reducing raw material consumption and, through a recycling programme, lower waste disposal costs, a reduction in energy and water consumption and effluent disposal	Recycling, re-use schemes	✓	
Waste	Environmental auditing, new waste sorting mechanism	Regular audits	✓	
Waste	Integrating waste management practice	Establishing key performance indicators	✓	
Water	Employee awareness and 'turn off' campaign	Training of employees	✓	
Water	Water monitoring	Monitoring of processes/use	✓	
Water	A full scale water investigation	Monitoring of processes/use	✓	
Water	Redesigning packaging	Mass balance	✓	
Water	Shelf-ready packaging trays, water recycling system	Recycling, re-use schemes	✓	
Energy	Overall energy efficiency, insulation,	Regular preventive maintenance	✓	
Energy	Meter installation, bill validation	Monitoring of processes/use	✓	
Energy	Turning lights and computers off	Training of employees		✓
Waste	Improving recycling	Recycling, re-use schemes		✓
Waste	Waste monitoring	Monitoring of processes/use		✓
Waste	Waste segregation, recycling	Recycling, re-use schemes	✓	✓
Materials	Increasing efficiency in the use of materials on site (this means fewer materials are purchased)	Mass balance		✓
Materials	Decreasing packaging	Mass balance		✓
Materials	Sourcing materials from within the local area of its operational sites	Monitoring of processes/use		✓

3.2.2 Employment Effects

With respect to employment, the case studies set out to establish the degree to which implementing quick-win resource efficiency measures would lead to changes in either of the two measures of employment discussed in Section 3:

- would it require additional or different inputs (i.e. does implementing the measure itself require additional jobs or does it require changing the job description/status of an existing position(s)); or
- would a quick-win measure lead to lower prices and thus increases in demand for a company's product, with this then leading to increases in employment.

Results drawn from the case studies and the consultation show that the primary focus of companies implementing resource efficiency measures is to retain jobs, rather than create additional ones. For newly implemented measures, enterprises are more likely to employ an external advisor initially and amend the job description of the adequate member of staff to include the additional tasks.

With regard to the actual employment changes resulting from resource efficiency measures, very limited information has been identified for either sector. The majority of key stakeholders consulted during the case studies were of the opinion that implementation of the different quick-win resource efficiency measures tends not to be directly linked to job creation. As noted above, companies are more likely to add to the job descriptions of currently employed staff, than to hire new employees for the specific tasks[19].

3.2.3 Competitiveness

In terms of changes in the competitive position of companies, the case studies looked at how costs savings resulting from different measures are being used. As Table 3.6 shows information in this regard is considered commercially sensitive and, as a result, limited data were available. Instead information based on general sector specific behaviour and market conditions has been gathered on the use of savings.

Figures given in Table 3.5 also indicate that businesses are able to yield substantial benefits with the implementation of a number of quick-win measures. Since costs affected by the implemented resource efficiency measures are strongly embedded into overall production costs (such as the cost of energy or waste), reductions could have an immediate effect on the total costs of production (and depending on market conditions on product prices). These measures are often implemented alongside other supplementary investments that can reinforce benefits.

More detailed information on the specific scenarios is given in the Annexes. This includes details on the nature and detail of the resource efficiency measures, such as the type of resources (water, waste, materials or energy), the level of costs savings realised, as well as any further impact these might have had on employment or competitiveness.

[19] Some information regarding Regional Development Agency programmes providing support to companies to implement resource efficiency measures has been incorporated into Table 4.1, although the statistics provided are for support to all sectors and not specifically focussed on the Food, Drink and Tobacco and Construction sectors.

Table 3.5: Summary of Estimated Savings from Resource Efficiency Measures							
Resource Efficiency Measure	**Industry**	**Company Size**	**Total Costs (or Project Costs)**	**Estimated Savings from Resource Efficiency Measure**	**Savings as % of Total or Project Costs**	**Any Further Details on Savings**	**Any Knock-on Impacts for Employment and Competition**
Waste: work with a local waste management contractor to set up a waste segregation yard	Construction	Turnover of > £900 million	Unknown	£20,000 per year	Waste costs decreased by 30%	-	Setting up the waste segregation yard provided additional employment for the local community
Waste: recycling packaged food products into constituent parts	Food and Drink	Turnover of $138 million (2008)	Unknown	Unknown	Costs associated with disposing of waste reduced by 50%	Modification of waste operations and focusing on recycling packaged food products into food, cardboard and plastic.	Employing just one waste contractor instead of the previous practice of employing seven different contractors
Waste: waste minimisation	Food and Drink	Turnover of £6.5million	Unknown	£56,700, further savings of £14,300/year	Waste disposal costs have fallen by £12000/year (66%)	Savings from minimising wastage of bakery products and frying oil of £3700/year; £28000/year from the reduction in fuel consumption and in the number of vehicles used.	Savings in labour costs of £13000/year suggests the company has cut the number of staff
Waste: Redesign of the transit packaging for a key account customer	Food and Drink	Unknown	Unknown	Unknown	Unknown	Increased the packing density of boxes on a pallet by 147%, allowing a higher weight to be carried per pallet. This has reduced handling, fuel and time costs. In addition, use of thinner cardboard in the boxes has reduced the weight of packaging waste generated by the end-user	-

Table 3.5: Summary of Estimated Savings from Resource Efficiency Measures							
Resource Efficiency Measure	**Industry**	**Company Size**	**Total Costs (or Project Costs)**	**Estimated Savings from Resource Efficiency Measure**	**Savings as % of Total or Project Costs**	**Any Further Details on Savings**	**Any Knock-on Impacts for Employment and Competition**
Water: Water efficiency campaigns	Food and Drink	Unknown	£15,000	Savings in excess of 20% of water usage equalling approximately 70,000 m^3 per year.	Unknown	-	-
Water: Replacing jet bars	Food and Drink	Unknown	£57,000	£200,000	Relative water savings of 8% across the business and a 16% reduction in m^3 of water used per tonne of milk	-	-
Energy: meter installation, self billing	Food and Drink	Profit before tax £239.1m	Unknown (£500 per meter fitted per site)	£3,000,000	Unknown	£1.2m claimed back through incorrect billing; re-negotiation of group tariffs, ensuring on-going savings of £1.0m per year for energy; reduction in water costs of £0.4m through reduced leakages and wastage; the activity contributed to Whitbread's 2.7% reduction of energy used that year, which represents a reduction of 10,600 tonnes in carbon dioxide emissions.	-

Table 3.5: Summary of Estimated Savings from Resource Efficiency Measures							
Resource Efficiency Measure	**Industry**	**Company Size**	**Total Costs (or Project Costs)**	**Estimated Savings from Resource Efficiency Measure**	**Savings as % of Total or Project Costs**	**Any Further Details on Savings**	**Any Knock-on Impacts for Employment and Competition**
Energy: monitoring and efficiency programme for electricity	Food and Drink	Turnover of £1 million	Unknown	£7,000	Utility costs reduced by 15%	Saving of £5,000 a year with utility costs reduced by 15% and an additional saving of £2,000 a year with the implementation of new waste minimisation and recycling programme.	-
Energy: Environmental Policy, CSR Statement, Energy Policy, Travel Reduction & Fleet Improvement & Vehicle Fuel Efficiency	Food and Drink	No. of employees: 12	Unknown	£3,600	Unknown	-	-
Energy: Energy Demand Management, Metering Paper/spreadsheet recording of utility bills Carbon Footprint	Food and Drink	No. of employees: 16	Unknown	£1,130	Unknown	-	-
Energy: Energy Demand Management, Metering Paper/spreadsheet recording of utility bills Carbon Footprint	Food and Drink	No. of employees: 18	Unknown	£3,975	Unknown	-	-
Energy: Energy Demand Management, Metering Paper/spreadsheet recording of utility bills Carbon Footprint, Awareness Campaign	Food and Drink	No. of employees: 40	Unknown	£3,062	Unknown	-	-

Table 3.5: Summary of Estimated Savings from Resource Efficiency Measures							
Resource Efficiency Measure	**Industry**	**Company Size**	**Total Costs (or Project Costs)**	**Estimated Savings from Resource Efficiency Measure**	**Savings as % of Total or Project Costs**	**Any Further Details on Savings**	**Any Knock-on Impacts for Employment and Competition**
Energy: Energy Demand Management, Metering Paper/spreadsheet recording of utility bills Carbon Footprint, Awareness Campaign	Food and Drink	No. of employees: 19	Unknown	£3,638	Unknown	-	-
Energy: Energy Demand Management, Metering Paper/spreadsheet recording of utility bills Carbon Footprint, Technology Change, Materials Demand Management	Food and Drink	No. of employees: 20	Unknown	£1,949	Unknown	-	-
Energy: Energy Demand Management, Metering Paper/spreadsheet recording of utility bills Carbon Footprint, Materials Demand Management, Re-use/Recycling, Awareness Campaign	Food and Drink	No. of employees: 20	Unknown	£726	Unknown	-	-

Table 3.5: Summary of Estimated Savings from Resource Efficiency Measures							
Resource Efficiency Measure	**Industry**	**Company Size**	**Total Costs (or Project Costs)**	**Estimated Savings from Resource Efficiency Measure**	**Savings as % of Total or Project Costs**	**Any Further Details on Savings**	**Any Knock-on Impacts for Employment and Competition**
Energy: Energy Demand Management, Metering Paper/spreadsheet recording of utility bills Carbon Footprint, Environmental Management Tool/System, Energy Demand Management, Technology Change, Materials Demand Management, Re-use/Recycling, Awareness Campaign	Food and Drink	No. of employees: 38	Unknown	£4,741	Unknown	-	-
Energy: Environmental Policy, CSR Statement Energy Policy, Energy Demand Management, Metering Paper/spreadsheet recording of utility bills, Environmental Management Tool/System, Energy Demand Management, Re-use/Recycling	Food and Drink	No. of employees: 23	Unknown	£4,072	Unknown	-	-
Energy: Energy Demand Management, Metering Paper/spreadsheet recording of utility bills Carbon Footprint	Construction	No. of employees: 5	Unknown	£569	Unknown	-	-
Materials: re-use of insulation	Construction	Unknown	Unknown	£6,000	Unknown	Diversion of materials sent to landfill	-

Table 3.5: Summary of Estimated Savings from Resource Efficiency Measures							
Resource Efficiency Measure	**Industry**	**Company Size**	**Total Costs (or Project Costs)**	**Estimated Savings from Resource Efficiency Measure**	**Savings as % of Total or Project Costs**	**Any Further Details on Savings**	**Any Knock-on Impacts for Employment and Competition**
Materials: diversion of excavated material away from landfill	Construction	Unknown	Unknown	£7,680 in cost savings and £6,400 in additional savings from gate fees	Unknown	Diversion of 2,560 tonnes of waste from landfill	Retention of two employees (involved with the transport of the excavated material)
Materials: use of recycled materials	Construction	Turnover of > £270 million	Unknown	£5,322,300 for 2007-08	Unknown	Diversion of over 2 million tonnes of waste from landfill	-
Materials: increased efficiency in the use of materials on site (this means fewer materials are purchased)	Construction	Unknown (but around 350 employees)	Unknown	£100,000 in disposal costs (by decreasing amount of materials used by 1,500 tonnes)	Unknown	Using fewer materials has knock-on impacts on the number of vehicle movements	-
Materials: recycling waste materials	Construction	Unknown (but > 2400 employees)	Unknown	£180,000 in revenue in one year through recycling waste materials	Unknown	-	-
Materials: recycling waste materials	Construction	Unknown (but > 2400 employees)	Unknown	£41,000 per year	Unknown	Diverting 2,500 tonnes from landfill each year	-
Water: decreasing water consumption	Construction	Unknown (but > 2400 employees)	Unknown	£6,000 per month (for a site which is 95% self-sufficient in water)	Unknown	-	-
Materials: decreasing packaging	Construction	Unknown (but > 2400 employees)	Unknown	Savings of £5,000 in landfill costs and gaining additional profits of £8,000	Unknown	Decreased amount sent to landfill	-

3.3 Sector Framework

3.3.1 Overview

This section reports the results of the analysis of the resource-efficiency savings identified in both the Oakdene Hollins study and the more indicative findings from the case studies undertaken for this project using the sector frameworks approach.

Table 3.6: Impact of Resource Efficiency Savings - Sector Framework

	Cost Saving	Price	GVA impact	Net Trade	Profit	Employment
	%	%	%	%	%	%
Oakdene Hollins						
Construction (S2a)	0.24	-0.25	0.06	n/a	0.04	0.06
Food, Drink & Tobacco (S1a)	2.36	-2.24	1.65	2.86	2.92	1.42
Case Studies						
Construction (S2b)	1.02	-1.04	0.23	n/a	0.17	0.24
Food, Drink & Tobacco (S1b)	0.87	-0.83	0.62	1.14	1.03	0.52

Table 3.6 shows the impact of the sets of resource-efficiency savings on the Construction and Food, Drink & Tobacco sectors. The impacts on competitiveness and employment are larger for the Food, Drink & Tobacco sector, relative to the size of the cost saving, than for Construction. This is a result of differences in the estimated econometric parameters which are discussed in the following sub-sections.

The case-study examples indicate a wide extent of impacts arising from low-cost/no-cost quick win measures. Where the driving force behind the implementation of the measure is primarily cost cutting, increases in employment are unlikely.

Consultation with a range of organisations operating at national level to promote and support resource efficiency measures indicates that whereas businesses in the Food, Drink & Tobacco sector are more likely to re-invest cost savings into their operation, Construction companies might use the savings to cut prices due to the intense competition that exists in this sector.

The implementation of resource efficiency measures can not only contribute to the reduction of production costs but can impact on the perception of a company as well. Recycling savings and reinvesting in their company's operation helps to maintain or improve competitiveness, along with other factors such as Corporate Social Responsibility, business-to-business relations, supply chain mechanisms etc. it helps companies in displaying a "greener" image and thus strengthening their reputation.

Obtaining even anecdotal evidence of how companies have made use of cost savings realised through resource efficiency measures has proved problematic (as expected). This is commercially sensitive information and it is understandable that companies do not wish to divulge such information. Consequently, we have been unable to obtain information as part of the case studies, nor have the limited responses to the survey provided any useful details.

We do know however that there is likely to be some limited information in possession of the Regional Development Agencies as a result of their support through various instruments to companies to improve resource efficiency. As part of a recent evaluation of the support provided between 2005 and 2009 to 2,206 businesses provided with information, advice and guidance to improve resource efficiency, increase productivity and competitiveness as part of the Envision programme, the SWRDA carried out a survey of businesses receiving support from the programme.

Businesses were asked a number of questions regarding their turnover, resource requirements and the use made of any savings. Table 3.7 below sets out responses regarding their use of the savings generated following implementation of advice and guidance provided.

Table 3.7: Uses Made of Cost Savings Resulting from Resource Efficiency Measures	
How savings are used	**%**
Retained within the business	32
Re-invested in business growth plans	36
Re-invested in other resource efficiency improvements	32
Savings withdrawn from the business as profit	0

Unfortunately, we were unable to obtain breakdowns of the information provided with respect to the particular sectors (although the majority of those receiving support were in the manufacturing sector), nor with respect to the specific measures that were implemented. However, the information, advice and guidance provided focused on the quick-win type of measures that are being considered here and so it is quite likely that the responses relate to these types of measure.

Results of the assessment indicate that enterprises are unlikely to be motivated merely by income generating purposes when implementing resource efficiency measures. As the above responses illustrate, the amount saved is most likely to be re-invested in the company's operation, or otherwise retained within the business - meaning accumulated income will be used as part of the equity section on the balance sheet or used possibly to implement further resource efficiency measures.

3.3.2 Sector Framework Results: Food, Drink & Tobacco

There are over seven thousand food and drink manufacturing companies in the United Kingdom employing over four hundred-thousand people directly and responsible for an additional 1.2 million jobs indirectly. Companies within the industry are mostly small to medium-size enterprises, employing on average between 100-250 people and generating £72.8bn of turnover and a value added of £21.5bn.

The following table on trends in output, productivity and employment illustrates the relationship between the productivity of the Food and Drink sector and employment rates.

Table 3.8: Trends in Output, Productivity and Employment in the Food and Drink sector				
Indicator	1997-2002	2002-2007	2007-2012	2012-2017
Output (% pa)	0.2	0.6	0.9	0.9
Employment (% pa)	-1.4	-2.1	-0.5	-0.8
(000s)	-34	-48	-11	-17
Productivity (% pa)	1.6	2.7	1.4	1.7
Source: UK Commission on Employment and Skills, Evidence report (2008) Working Futures 2007-2017				

According to the UK Commission for Employment and Skills Working Futures 2007-2017 evidence report, the machine operatives category is the most important occupational group accounting for 1 in 4 of all jobs. Demand for skilled trades and elementary occupations have fallen sharply and according to projections it will continue to do so in the coming decades;

other categories such as managers, associate professionals and sales and customer service occupations have seen increases with regard to their shares of total employment.

With regard to the Food and Drink sector, our consultation has indicated that employment is unlikely to increase due to implemented low-cost/no-cost quick-win resource efficiency measures. Companies often implement these measures with cost cutting purposes and are consequently more likely to invest in external consultants in order to implement resource efficiency measures than to add to their workforce increasing their fixed costs. Even though the demand for additional jobs remains largely unaffected, certain skills are likely to be added to existing tasks, presenting new embedded knowledge within the sector.

For the Food, Drink & Tobacco sector we estimate a 2.36% decrease in costs as a result of the resource efficiencies described in the Oakdene Hollins study. As described in the methodology chapter, the impact the cost saving has on our measures of competitiveness and employment depends initially on how the firm responds to changes in cost.

We estimate that the cost pass-through for this sector to be 95%, which means that a 1% decrease in unit cost is estimated to result in a decrease in price of 0.95%. This is in line with our expectations that for a fairly competitive industry, like Food, Drink & Tobacco, the pass-through rate will be close to one and any cost savings will result in a lower price for consumers. Prices are therefore reduced by 2.24% as a result of the resource-efficiency savings. Because only 95% of the cost savings are passed on through prices, we assume that the remaining 5% is retained as sector profits. In the sector framework, because we assume all other things to remain equal, this change in domestic price is also assumed to be reflected in export prices.

The impact on price leads to a demand response, both domestically and abroad. Domestic demand covers UK consumers' demand for Food, Drink & Tobacco from domestic production and imports – it therefore comprises two key components of final demand and is derived as domestic production, less exports, plus imports.

We estimated a price elasticity of domestic demand for Food, Drink & Tobacco of -0.54. The coefficient on imports is also inelastic, but positive, at +0.1. These results indicate that UK consumers' marginal rate of substitution from imports of Food, Drink & Tobacco to domestic production is greater than one. In turn, this means that UK consumers do not view imports and domestically-produced Food, Drink & Tobacco as perfect substitutes. The principal income driver of domestic demand for Food, Drink & Tobacco was household expenditure. As a result of the domestic demand response, a fall in prices of 2.24% leads to an increase in domestic demand of 1.22%.

We also found that export volumes increased as a result of lower export prices.

Overall, resource-efficiency savings lead to an increase in net trade (the balance of export and import volumes) of 2.86%. When combined with the impact on domestic demand this leads to an increase in gross output of 2.21%.

The total impact on profit is the combined impact of the resource-efficiency cost savings which are not passed on through prices and the impact of increased output, assuming a constant profit margin. The sector framework suggests that profit will increase by 2.92%.

The Food, Drink & Tobacco industry is a capital-intensive industry, and so, from our econometric analysis, all other things being equal, a 1% increase in industry output is estimated to lead to a 0.64% increase in employment. Therefore, we see an increase in employment of 1.42%, equivalent to around 5,600 jobs (on a full-time equivalent basis). Of these, assuming the structure of employment in the industry does not change, this will predominantly be met by males in full-time employment (3,700) and then females in full-time employment (1,500). A small minority of the new jobs will be met by part-time employees.

In summary, the evidence from the sector framework overall suggests that resource-efficiency savings will have a positive impact on the Food, Drink & Tobacco sector's competitiveness as measured by our indicators. Equally, as a result of the increase in output we find evidence for small increases in employment, but the case studies do not identify that any changes to employment are necessary to implement the resource-efficiency savings. In other words, the jobs created are a result of an increase in demand for a product rather than through the creation of 'green' jobs required to bring about the resource-efficiency savings.

The sector framework is relatively simple compared to the whole-economy modelling approach in MDM-E3. As such, the impact as a result of using resource-efficiency cost savings arising from our own analysis is an increase in competitiveness almost directly in line with the differences in resource efficiency cost savings as compared to the Oakdene Hollins figures. In other words, if our resource efficiency savings are 10% larger than those in Oakdene Hollins, the impact on the change in output is 10% larger.

3.3.3 Sector Framework Results: Construction

With regard to the Construction sector, the trend growth has been affected by the recent economic downturn. However, all sub-sectors of the industry are expected to see increases in output growth, with infrastructure and public housing anticipated to be the most buoyant.

Annual Business Inquiry (ABI) data[20] collected using the UK Standard Industrial Classification (SIC) 2007 system indicate that total turnover for the Construction sector in 2008 was £227,613 million. A total of 292,779 firms were involved, contributing to a GVA of £91,199 million. The data for 2003-2007 are shown in Table 3.9. Please note that since these were collected under the SIC (2003) system, they are not strictly comparable with the 2008 data. However, they provide an indication of the main trends.

Table 3.9: Summary of Main Statistics for the Construction Sector, 2003-2007

Year	Total Turnover (£ million)	Number of Enterprises	Approximate Gross Value Added (GVA) at basic prices (£ million)	Total Employment (average during the year) (thousand)	Total Stocks and Work in Progress – increase during the year (£ million)
2003	150,892	200,546	53,150	1,329	2,246
2004	158,025	209,172	55,636	1,347	2,159
2005	166,312	220,666	63,308	1,393	2,232
2006	175,770	229,181	67,579	1,394	1,228
2007	196,185	240,367	74,656	1,431	2,162

Notes: data are extracted from Annual Business Inquiry and have been collected under SIC(2003). See Office for National Statistics (http://www.statistics.gov.uk/abi/) for further information.

In 2005, 2.41 million people were employed in Construction and that figure is expected to rise to more than 2.8million by 2011. Over the seven years this would represent an employment increase of 17.5%. To deliver this growth and replace those who will leave the industry an average of 87,600 new workers would need to be recruited per year, a slightly higher number than estimated over the 2006-2010 period.

[20] See Office for National Statistics, http://www.statistics.gov.uk/abi/

The Construction sector differs substantially from the Food, Drink & Tobacco industry in a number of key ways:

1. it is labour-intensive rather than capital intensive;
2. there is very little trade in Construction; and
3. the Construction sector is highly competitive.

These observations are mostly backed up by the findings of the econometric analysis and help to explain the differences in the findings between the two sectors.

Broadly, the impacts of the resource-efficiency measures identified for the Construction sector are smaller than for Food, Drink & Tobacco. One key reason for this is that a resource-efficiency saving of £254m is a substantially smaller proportion of total cost for the Construction sector (0.24%) than the same saving would be for the Food, Drink & Tobacco sector (0.64%).

In the Construction sector, the cost savings are passed on in full suggesting higher levels of competition than the Food, Drink & Tobacco sector. In fact our estimates suggest that the pass-through rate is actually slightly larger than one (1.02). While this is just statistically significantly different from one, in economic terms it is really just full (100%) cost pass-through.

As a result of the fall in price brought about by the efficiency savings, there is an increase in domestic demand of 0.05%, the result of a price elasticity of demand of -0.22, far lower than that estimated for Food, Drink & Tobacco. In our econometric analysis we found GDP to be the principal driver of demand for Construction, which is in line with our intuition.

However, for the Construction sector we were unable to find a statistically-significant relationship between trade and trade prices. This is largely to do with the industry: trade in construction is negligible compared to domestic demand. Therefore, we believe it is valid to assume that prices do not impact on trade volumes through increased export-market penetration or lower imports. As a result, the impact on gross output (the total turnover of the sector), grows in line with the impact on domestic demand, by 0.05%.

As all cost savings are passed on through reductions in price, none of the cost savings are retained as sector profit, as such the change in sector profit is just 0.05% and, consequently, the increase in GVA is just 0.06% because of the increase in wages as a result of increasing employment.

The increase in output does have an impact on employment, which is a key input in the Construction sector. As such a 0.05% increase in gross output leads to a 0.06% increase in employment. This is equivalent to around 700 jobs (on a full-time equivalent basis), nearly all of which are met by males in full-time employment (nearly 600 jobs) based on the current employment structure of the industry. The case studies did not find evidence of direct employment requirements to realise the resource-efficiency savings. This is probably due to the nature and small scale of the savings achievable through no/low cost resource efficiency savings.

In summary, both the relative size of the resource-efficiency cost savings and the relative impact of those cost savings are smaller in the Construction sector than in Food, Drink & Tobacco, but this is not an unexpected result given our *a priori* understanding of the economic characteristics of the two sectors.

3.4 Whole-economy Modelling Approach

3.4.1 Overview

This section presents the results from the whole-economy modelling carried out in CE's MDM-E3 model of the UK economy to quantify the macroeconomic impacts of resource efficiency. The purpose of this part of the analysis is to assess the impacts on the wider economy of resource-efficiency measures that were implemented in a specific industry sector. By contrast, the sector framework simply looks at the net effect on the sector in isolation and, by design, ignores complex inter-industry relationships and whole economy feedbacks The analysis described in this section takes the form of comparisons between scenarios of alternative projections of resource efficiency against a baseline (or business-as-usual [BAU]) projection. In the model, the resource-efficiency measures were implemented in 2010. The results in this section are presented largely as percentage differences between the alternative projections and the BAU by 2015; this five-year horizon gives time for the longer-term dynamic relationships in the model to take effect. This is also useful for the purposes of comparison with the static sector frameworks (see Section 4.1 for comparison and Section 4.3 for a discussion of the sector framework results).

The BAU projection is based on CE's first round of UK forecasts published in 2010, as presented in the January 2010 edition of *Industry and the British Economy* and the May 2010 edition of *UK Energy and the Environment*[21]. These forecasts are produced using MDM-E3.

The results of the whole-economy modelling undertaken are summarised in Table 3.10.

Table 3.10 Impact of Resource Efficiency Savings – Whole-Economy Modelling (%)

	Unit cost	Price	GDP	GVA impact	Employment	Net trade
Oakdene Hollins						
Construction (S2a)	-0.28	-0.27	-0.01	0.47	-0.15	n/a
Food, Drink & Tobacco (S1a)	-2.07	-1.44	-0.02	5.21	-0.49	0.56
Case Studies						
Construction (S2b)	-0.96	-0.91	-0.12	1.80	-0.65	n/a
Food, Drink & Tobacco (S1b)	-0.80	-0.57	0.01	1.74	-0.27	0.17

Note(s): Results are presented as the percentage-difference impact of implementing resource-efficiency savings as opposed to the cost increases actually modelled. Results are for 2015.

3.4.2 The Scenarios

Because the resource-efficiency savings identified have already been implemented in the historical period, the baseline projection we have used (which is based on historical data and past relationships) already accounts for these savings. As such, the scenarios modelled represent states of the world in which the savings were not implemented; we have modelled cost increases in the scenarios and the baseline is our 'resource-efficiency scenario'. Nevertheless, for presentational purposes, the results presented in this section have been

21 http://www.camecon.com/UK/UKEnergy/PressRelease-UKEnergy.aspx

framed as the economic impacts of implementing resource efficiency, as opposed to the impacts of 'removing' the efficiency savings i.e. we will refer to efficiency savings rather than costs increases. We consider this to be a more intuitive way of thinking about these savings.

As in the analysis using the sector framework, four alternative sets of resource-efficiency savings were assessed, leading to four scenarios (see Section 3.1).
In contrast to the sector frameworks, the whole-economy modelling approach in MDM-E3 requires assumptions on the inputs (and the producing sectors) that relate to the cost savings. Energy and water-related savings are easily allocated to the relevant sectors. In the case of materials/waste, in the absence of additional detail, the savings were typically allocated to reductions in purchases that accounted for the largest shares of intermediate demand. These are identified in Section 2.5.3 and also presented in Table 3.11, alongside the calculated breakdowns of savings.

Table 3.11: Resource Efficiency Savings, by Supply Sector (£2005m)

	Oakdene Hollins		Case Studies	
	FDT	Construction	FDT	Construction
	S1a	S2a	S1b	S2b
Agriculture	223			
Food, Drink & Tobacco			82	
Wood & Paper		18		203
Rubber & Plastics	105	20		231
Non-Metallic Mineral Products		32		350
Metal Goods		25		270
Electricity Supply	73	26	55	
Water Supply	57	2	7	
Distribution	481	130	197	
Miscellaneous Services				4
TOTAL	939	254	341	1058

Notes: FDT is Food, Drink & Tobacco.

The changes presented above are the only inputs to the whole-economy modelling approach; all secondary effects (both those in other sectors as well as further effects in the industries being analysed) arise as a result of the relationships in the model. When examining the results below it is perhaps worth considering some of the limitations of the MDM-E3 modelling approach:

- it is based on past relationships which may not hold true into the future
- the empirical estimation technique assumes that relationships are symmetrical, so that both cost savings and cost increases are passed on to consumers in the same way
- the results are highly dependent on the inputs from surveys and secondary sources, and
- the results do not consider intra industry competition.

3.4.3 Results for the S1 Scenarios: Food, Drink & Tobacco

The S1 scenarios model two alternative sets of resource-efficiency savings in the sector defined in MDM-E3 as Food, Drink & Tobacco.

The effect of the resource-efficiency gains is a reduction in the unit cost of production of Food, Drink & Tobacco products by 2015 of 2.1% when considering the S1a scenario (in which the resource efficiency savings were based on the Oakdene Hollins and Grant Thornton [2007] results) and 0.8% from the S1b scenario (savings calculated from the case study results). This result is consistent with the substantially larger savings identified for S1a compared to S1b; the S1a savings, in total, are almost 2.5 times larger.

The impact on final prices is unsurprisingly somewhat smaller owing to some of the savings being retained by firms in the form of higher profits ie cost pass-through for this MDM-E3 sector is less than 100%. The savings identified for S1a indicate a reduction in the final price of domestic Food, Drink & Tobacco production of 1.5%; the reduction from the case study savings is around 0.6%. The effect of the price reductions on demand are modest: the resource-efficiency savings identified in the Oakdene Hollins and Grant Thornton (2007) study suggest that the price reduction afforded by the savings leads to an increase in household expenditure (consumption demand) of 0.14% in 2015. The case study estimates suggest a smaller increase still of 0.05% in 2015.

The competitiveness effects of the price reductions are clear from S1a: the savings lead to an increase in export demand of 0.4% by 2015. There is little change in S1b. Conversely (and as expected) import supply of Food, Drink and Tobacco products falls slightly owing to domestic production being priced more competitively as a result of the resource-efficiency savings.

Production of Food, Drink & Tobacco products must respond to meet higher demand. This is reflected fully in the differences in gross output from the industry when S1a is compared to the baseline (higher demand drives higher output). When considering the S1b scenario, however, gross output is actually reduced slightly (by less than 0.1%) by 2015 as a result of the efficiency measures. The reason for this is that some of the efficiency savings identified in the case studies (such as less wastage of bakery products and frying) have been translated into reductions in intermediate demand for Food, Drink & Tobacco products *from* the Food, Drink & Tobacco industry. That is, intra-industry purchases of inputs to production are reduced as a result of the resource-efficiency savings. This reduction in intermediate demand is the reason for the overall, albeit slight, reduction in Food, Drink & Tobacco gross output. Reductions in other industries' gross output from the resource-efficiency savings occurs for similar reasons: because reductions in intermediate demand tend to outweigh the effect of lower prices on (final) demand. This is most noticeable for those sectors that supply inputs to Food, Drink & Tobacco production, for example Agriculture, Rubber & Plastics (packaging) and Water Supply, which will have seen reductions in intermediate demand as a result of resource-efficiency savings.

The less-than-100% pass-through of costs to price can also be seen, to some extent, by the increase in GVA (which includes profit) of the sector: 5.2% by 2015 from the S1a savings and 1.7% from the S1b savings.

Interestingly, both scenarios see a reduction in employment, which occurs for different reasons. In Scenario S1a, the scenario that examined the implied Oakdene Hollins and Grant Thornton (2007) cost savings, the increase in output leads to an increase in the model's measure of 'normal' output, which is a measure of sustainable longer-term economic capacity. Meeting this higher expectation of output is associated with longer working hours in MDM-E3, for this particular sector, and as a result worker productivity (as measured by hours worked) rises over the projection period; the level of employment in

Food, Drink & Tobacco adjusts for the increased productivity and the Oakdene Hollins and Grant Thornton (2007) cost savings are associated with a reduction in employment of 0.5% by 2015.

The mechanism by which employment falls from the savings estimated from the case studies, by 0.3%, is simpler and occurs because gross output (production) is reduced as a result of the reduction in intra-industry intermediate demand. Lower output reduces the requirement for labour and thus employment falls.

In both scenarios, the macroeconomic impacts in terms of GDP are negligible as a result of the resource-efficiency savings (overall they are very slightly negative owing to reductions in output from some sectors) and total import and export volumes change little. This is perhaps to be expected given that the reductions modelled were meant to represent the quick wins available to improve resource efficiency. The most noticeable change at this aggregate level is a reduction in the general price level (the implied GDP deflator) by 2015 of 0.14% from S1a and 0.05% from S1b.

The reductions in energy consumption brought about by the energy-related resource-efficiency savings implemented in this modelling approach were small and led to negligible changes in electricity prices[22]. As such, there is little evidence of a rebound effect in energy demand in the scenarios modelled. In any case, on this scale, the principal driver of increased energy demand remains demand for industrial production, which is a relatively much larger effect in these scenarios.

3.4.4 Results for the S2 Scenarios: Construction

In contrast to the resource-efficiency savings modelled for Food, Drink & Tobacco, the Oakdene Hollins and Grant Thornton (2007) study implies more conservative efficiency gains for Construction compared to those derived from the case study data. The savings estimated from the case studies are almost four times as large as those calculated from the Oakdene Hollins and Grant Thornton (2007) study. By value, the two sets of total savings identified for Construction for the two scenarios are not substantially different to those calculated for Food, Drink & Tobacco.

Construction unit costs are 0.3% lower in 2015 from the resource-efficiency savings based on the Oakdene Hollins and Grant Thornton (2007) figures used in S2a. The larger savings derived from the case studies suggest a larger reduction, of 1%. The cost pass-through for this sector is nearer 100% than the pass-through for Food, Drink & Tobacco and, as such, the reductions in the final price of Construction goods are very close to the reductions in cost. The resource-efficiency measures lead to an increase in price competitiveness and the lower price, all other things being equal, leads to an increase in demand for UK Construction goods. Despite the high levels of cost pass-through, because GVA accounts for some two-fifths of gross output from Construction, the profit retained contributes to increases in GVA of 0.5% based on the S2a savings and 1.8% based on the S2b savings.

However, the analysis undertaken to analyse the whole-economy effects does not hold all other things constant (in contrast to the sector frameworks); the economic system embodied in MDM-E3 is more complex and captures a much wider range of interactions. These other linkages suggest that the whole-economy effects originate more from the reduction in intermediate demand from Construction, outweighing the price effects on final demand. The

[22] The nature of electricity generation in the model is such that demand for electricity is met, where possible, by the cheapest generation technologies; as demand increases, more costly forms of generation must be brought online, driving up the cost of electricity. Thus, at least in the first instance, a reduction in electricity demand from a particular sector will typically lead to a reduction in price.

impacts of resource efficiency in Construction have implications for industries further up the supply chain.

The supply-chain impacts can be seen in lower gross output from the sectors that supply inputs to production for which the Construction industry has implemented resource-efficiency measures. This is most evident in the analysis of the case study measures in S2b, which sees relatively large percentage reductions in output (falls greater than 1%; some appreciably larger) from the following MDM-E3 sectors:

- Wood & Paper (-1.7%);
- Rubber & Plastics (-5.1%);
- Non-Metallic Mineral Products (-3%); and
- Metal Goods (-1.8%).

Reductions in these sectors' output have knock-on effects to their suppliers, including some engineering sectors and Basic Metals. Output from Construction is not directly affected by the resource-efficiency savings; the impact on output is felt further up the supply chain, which is longer for Construction compared to Food, Drink & Tobacco.

The model results suggest that the implementation of resource-efficiency measures in Construction leads to a reduction in UK output, although the reduction in Construction is relatively small. Lower output leads to lower employment as well as lower wages (workers have less bargaining power because the pool of replacement workers is larger owing to lower economy-wide employment). This in turn leads to lower incomes and thus lower spending (lower final demand) in the economy. Lower final demand leads to lower production and so on (the multiplier effect), illustrating the inter-relationships represented in the MDM-E3 model.

Employment is 0.2% lower in 2015 as a result of the resource-efficiency measures analysed in S2a and 0.7% lower from the measures analysed in S2b.

The reductions in output and incomes lead to some reduction in GDP in 2015 as a result of the resource-efficiency savings. The impact of the S2a savings is slight, while the reduction as a result of the case study-derived resource-efficiency savings is just over 0.1%. The range and scale of the impact on general prices is similar to those in the Food, Drink & Tobacco scenarios.

As with the S1 scenarios, the energy efficiencies modelled were small and the evidence of rebound thus quite limited.

4 Conclusions and Interpretation

4.1 Overview

This project set out to examine, through the development of an econometric model and analysis of specific businesses (such as resource use, best practices, cost reduction measures and employment), the impact that 'quick-win' resource-efficiency measures have on competitiveness and employment in sectors of the UK economy (specifically, Food, Drink & Tobacco and Construction) and how these might affect the UK economy as a whole.

Case studies and literature reviews were undertaken to identify and extract information regarding specific resource-efficiency measures adopted by companies and their outcomes in terms of cost savings, employment and changes in competitive behaviour. The purpose of this analysis is to answer the following questions:

- which resources are concerned: water, waste, materials or energy?
- how were the cost savings realised?
- what was the level of cost saving?
- what was the principal driver behind making the efficiency savings?

The aim of the final question was to determine whether the impacts were the result of policy or a result of company cost cutting measures (or some other driver). It is not anticipated that this would necessarily affect the impact, but it is important for assessing the impact of policy intervention.

The studies have also identified the main legislative and non-legislative drivers which encourage, initiate and require changes in resource-efficiency behaviours in companies. Additionally, the consultation provides information on the implementation of the different measures and identifies the most important drivers in practice. Stakeholders have identified Corporate Social Responsibility, legislation, cost cutting and the desire to retain market share as the principal drivers behind the implementation of quick-win measures.

Limited information has been collected to demonstrate the effects – gains and losses - on jobs resulting from the implementation of resource-efficiency measures in the Food, Drink & Tobacco and Construction sectors at a company level. Although we were able to develop a link between increased competitiveness leading to greater output leading to greater employment, consultation with stakeholders has shown that the implementation of the different resource-efficiency measures is not directly linked to job creation and that companies are more likely to retain employees or to add to existing job descriptions than to hire new employees for any new tasks arising from the implementation of a measure. Thus, resource-efficiency measures may be important to ensure job retention and stability in some sectors (i.e. avoiding job losses) rather than leading the creation of a significant number of new green jobs.

To interpret the impacts of resource-efficiency savings on competitiveness and employment we have conducted two distinct pieces of analysis:

- the development and application of a framework for sector-specific analysis; and
- more complex whole-economy modelling using CE's MDM-E3 model of the UK.

The scope of the two tools is different which, unsurprisingly, leads to differences in the results we observe. The sector framework is a comparative static framework designed to look at the one-off impacts of resource-efficiency on employment and competitiveness. This was done by developing the structure of the sectors to relate cost savings to impacts on prices, changes in demand, output and trade, and employment. The sector framework was used to assess the impacts of the resource-efficiency savings identified in both the Oakdene Hollins (2007) study and the case studies. By contrast, the MDM-E3 model is a dynamic model of the whole economy. The purpose of implementing the resource-efficiency savings in this model was to test the impact of resource-efficiency savings within specific sectors on their supply industries and whether this was affected by the feedbacks from the wider economy.

Within each framework we implemented four scenarios: for each of our two sectors, Construction and Food, Drink & Tobacco, we assessed the impact of two alternative estimates of resource-efficiency cost savings. One set of estimates was taken from the Oakdene Hollins (2007) study on resource-efficiency savings and the second was taken from our scaled-up sector estimates of the findings from the case studies. These scenarios can be summarised as:

- Scenario 1a: Food, Drink & Tobacco, Oakdene Hollins and Grant Thornton:
    - this scenario analyses the resource-efficiency savings calculated for the Food, Drink & Tobacco industry, based on the earlier work by Oakdene Hollins and Grant Thornton (2007);

- Scenario 1b: Food, Drink & Tobacco, Case Studies:
    - in this scenario, Food, Drink & Tobacco is analysed using savings calculated from the case study findings obtained in this project;

- Scenario 2a: Construction, Oakdene Hollins and Grant Thornton:
    - this scenario analyses the resource-efficiency savings calculated for the Construction industry, based on the earlier work by Oakdene Hollins and Grant Thornton (2007);

- Scenario 2b: Construction, Case Studies:
    - in this scenario, Construction is analysed using savings calculated from the case study findings obtained in this project.

4.2 Competitiveness

Competitiveness remains an elusive concept to quantify, but we have selected a number of key indicators to assess the impact of resource efficiency on competitiveness at the sector level:

- industry prices;
- GVA;
- profit; and
- net trade.

For all scenarios and in both modelling approaches we find that the industry price is reduced as a result of the resource-efficiency savings, suggesting that because firms in our example sectors are competitive, part of the cost savings might eventually be passed on to consumers.

Table 4.1: Impact of Resource Efficiency Savings on Competitiveness Indicators (%)				
	WE/SF	Cost Saving	GVA impact	Net Trade
Oakdene Hollins				
Construction (S2a)	WE	0.24	0.47	n/a
Construction (S2a)	SF	0.24	0.06	n/a
Food, Drink & Tobacco (S1a)	WE	2.36	5.21	0.56
Food, Drink & Tobacco (S1a)	SF	2.36	1.65	2.86
Case Studies				
Construction (S2b)	WE	1.02	1.8	n/a
Construction (S2b)	SF	1.02	0.23	n/a
Food, Drink & Tobacco (S1b)	WE	0.87	1.74	0.17
Food, Drink & Tobacco (S2b)	SF	0.87	0.62	1.14

Note(s): WE = whole economy modelling, SF = sector framework.
S1a – Food, Drink & Tobacco, Oakdene Hollins
S1b – Food, Drink & Tobacco, Case Studies
S2a – Construction, Oakdene Hollins
S2b – Construction, Case Studies

Beyond this we observe different impacts on demand. In the sector frameworks we observe the static response, all other things remaining equal that demand increases as a result of the price reduction. For Food, Drink & Tobacco this has a substantial positive impact on net trade (the balance between import and export volumes), with domestic production becoming preferable to imports and an increase in export-market penetration. The reason for this is that the prices of goods produced in other countries that trade with the UK are assumed to be unchanged as a result of the UK implementing no/low-cost resource-efficiency measures. Resource-efficiency measures undertaken in the UK lead to price reductions that make domestically-produced goods relatively cheaper than imports (domestic production becomes preferable to imports). UK-produced goods are also cheaper overseas when compared to other countries' domestic production; UK exports increase. In the whole-economy modelling this impact is reduced, mostly because import prices respond to the change in domestic prices. For Construction, the impact on net trade is negligible because imports and exports are very small compared to the sector's gross output.

In terms of domestic demand, the results suggest that the secondary impacts can outweigh the first-round static impacts that we observe in the sector framework. This is highlighted in the results for Construction because the resource savings have a large impact throughout the supply chain. In other words there is a systematic reduction in demand throughout the supply chain. Overall this leads to economy-wide reductions in employment and in turn, income, which ultimately leads to diminished domestic demand for the sector and the economy as a whole. In other words, we observe the multiplier effect from the reduction in demand for products which arises from the resource efficiency. However, the overall effect is small with economy-wide employment falling by just 0.2% compared to the baseline.

However, for all scenarios, and in both modelling approaches, sector GVA increases as a result of the resource-efficiency savings. This is because it is comprised not only of the changes in demand, but because any amount of the costs not passed-through to prices is retained in profits (a component of GVA). However, in the wider-economy modelling in MDM-E3, GVA is reduced in a number of other sectors, predominantly the resource-supplying sectors.

The policy implication is that while resource-efficiency savings might not increase overall output, they seem to lead to lower industry prices and increase net trade, GVA and profits; by the measures we have defined, competitiveness does appear to improve. However, the impact is considerably reduced as a result of the whole-economy interactions (i.e. if further feedbacks are allowed). Moreover, the overall balance in the economy might well be negative because the resource supply sectors are so adversely affected.

4.3 Employment

The results from the sector-framework analysis suggest that resource efficiency leads to an increase in output for both sectors under both sets of resource-efficiency measures. In the sector frameworks, increased output drives increased employment and, as such, we see a small increase in employment in Construction, where the output increase is smaller, and a comparatively larger increase in Food, Drink & Tobacco (see Table 4.2). The output-employment relationship is relatively simple and, when compared to a more detailed model, may be a shortcoming of this approach. Moreover, because the frameworks only focus on the sector of interest, the potential impacts on employment in the rest of the economy are not accounted for.

Interestingly, there was negligible evidence of additional 'green' jobs (jobs which bring direct environmental benefit, eg waste management) required to bring about the resource-efficiency savings. We believe that this is a direct result of the type of resource efficiencies we are investigating, no/low-cost resource efficiencies are quite small, if extra jobs were required to realise the savings they might well not be worthwhile to an individual company seeking to minimise its cost base. This finding suggests that the motive for resource efficiency in companies is cost reduction rather than the environmental gain.

In direct contrast to the sector framework results employment is reduced in the MDM-E3 scenarios because of the aforementioned impacts on other sectors of the economy (through the model's representation of supply chains) and because of dynamic adjustment effects (see Table 4.2). For Construction the logic for this is relatively simple, the indirect (or second round) effects of the impact of reduced output in resource-supplying industries and the impact this has on wider economy activity and income, outweighs the initial static effect observed in the sector framework. This occurs because of the size of the multiplier effect, as a direct result of the length of the supply chain and the domestic production to import ratio of the resource supplying firms. In other words if the resource supply chain was short and predominantly imported, an example might be the supply of natural gas, the impact on the economy might well be positive, but because the various resource supply chains are made up of a number of predominantly domestic (and interrelated) the impact on the whole economy is relatively severe, given the scale of the efficiency savings. As demand for the resource supplying sectors decreases, output and employment, leading to a reduction in incomes. The reduction in incomes then impacts on household expenditure levels and overall, Construction output is reduced and therefore sector employment also falls, albeit by very small amounts.

Table 4.2: Impact of Resource Efficiency Savings on Employment(%)

	WE/SF	Cost Saving	GVA impact	Employment
Oakdene Hollins				
Construction (S2a)	WE	0.24	0.47	-0.15
Construction (S2a)	SF	0.24	0.06	0.06
Food, Drink & Tobacco (S1a)	WE	2.36	5.21	-0.49
Food, Drink & Tobacco (S1a)	SF	2.36	1.65	1.42

Table 4.2: Impact of Resource Efficiency Savings on Employment(%)				
	WE/SF	Cost Saving	GVA impact	Employment
Case Studies				
Construction (S2b)	WE	1.02	1.8	-0.65
Construction (S2b)	SF	1.02	0.23	0.24
Food, Drink & Tobacco (S1b)	WE	0.87	1.74	-0.27
Food, Drink & Tobacco (S2b)	SF	0.87	0.62	0.52
Note(s): WE = whole economy modelling, SF = sector framework. S1a – Food, Drink & Tobacco, Oakdene Hollins S1b – Food, Drink & Tobacco, Case Studies S2a – Construction, Oakdene Hollins S2b – Construction, Case Studies				

For Food, Drink & Tobacco the interpretation of the results is more complex. The Oakdene Hollins scenario leads to an increase in output but a decrease in employment. This arises because the increase in output is met by an increase in hours worked (i.e. an increase in labour productivity). This occurs because in the past, this sector typically responds to increases in demand by increasing hours rather than number of employees, in part this is because of the nature of the sector. As a capital intensive sector, less labour input is required to produce an additional unit of output, and because the industry often has flexible working arrangements (shift work, paid overtime) it is easier to increase workers hours than increase employment. It also occurs because hours worked are relatively low compared to the long term normal hours average for this sector. Interestingly the increase in hours worked persists and overshoots the demand, as a result employment decreases slightly by the end of the period to 2015. When analysing the case-study cost savings, rather than the Oakdene and Hollins cost savings, we see a reduction in industry output, as a result of intra-industry linkages: the sector demands less inputs from itself as a result of resource efficiencies and this leads to a fall in employment.

Our conclusion, therefore, is mixed with regard to the impact of resource-efficiency on employment for these two sectors. While we do not observe any evidence for ‘green’ jobs, it is less obvious what the employment effects will be as a result of changes to output, as it will depend on the complexities of the labour market, both for the sector and the economy as a whole, and the degree of influence of the business cycle (in terms of the ratio between hours worked and ‘normal’ hours worked which is the long term average) on the response of a sector to an increase in demand, as this will affect the degree to which increases in output are met by employment rather than additional hours worked.

4.4 Concluding Remarks: Method

The key objective of this research was to develop a method to assess the impact of resource efficiency on competitiveness and employment. At the start of this research we therefore faced some immediate challenges. First, we needed to define resource efficiencies, could we use a typology which would clarify the analysis. For the purposes of this project we focussed on no/low cost resource efficiencies. This decision was made partly because a wider evidence base on now/low cost measures had already been collated and partly because it simplified the already complex research question. This decision shaped the methodologies we developed in two ways: we didn't need to concern ourselves with the problem of analysing the impact of investment expenditure required for larger resource efficiency savings; and we were also no longer concerned with the issue of the payback period and, more generally, the dynamics of the impacts were not as important. The decision to focus on no/low cost measures also impacted on the results; particularly with regard to green jobs, as no/low-cost resource efficiency savings are often driven by cost-cutting motives and as a result do not lead to (green) job creation. Moreover, while differentiating between types of resource efficiency savings was helpful from an analytical point of view, it was clear from company responses in the sector case studies, that firms couldn't easily differentiate between no/low cost resource efficiency savings and investment-led resource efficiency savings. Finally, the focus on now/low cost measures meant that an econometric whole economy model, rather than a CGE model, was employed: it is conceptually difficult to represent x-inefficiency savings in models of perfect information and no transaction costs, as it raises the question of how the inefficiency came to exist in the first place.

Second, we needed to consider the level of detail we focussed on, company level, sector level or economy wide. The policy question is interesting at all three levels of granularity because there are different implications for competition and employment at each level. A company might be more cost competitive as a result of resource efficiency which might enable higher profits, or capturing greater market share, but have no (or little) impact on the sector aggregates as the increase in competitiveness would simply displace activity from other firms. Similarly, when considering employment, it is not enough to consider the net impacts on a sector's employment without considering the potential that jobs might be displaced elsewhere. We decided to gather evidence at each level using the case studies to identify qualitative company level information, the sector frameworks to represent the impacts on the sector, and whole economy modelling to capture both sector impacts and the wider economy implications. This was an important decision as it highlighted that both a quantitative and qualitative approach is required to form a robust evidence base with the richness of analysis required. The use of two modelling approaches also highlighted the fact that taking a sector in isolation is not satisfactory for this type of analysis because the wider economy impacts have important consequences for all sectors.

Third, it was hoped that the approach could also identify the drivers of resource efficiency, whether the resource efficiencies recorded were caused by regulation, policy, or market-led cost pressures. While we immediately recognised that this would be difficult to quantify we attempted to qualitatively assess the drivers for resource efficiency through the case studies.

Fourth, while the choice of sectors (Food, Drink and Tobacco, and Construction) was mostly driven by policy relevance and the scope for resource efficiency, it should be noted that the selection of two sectors which map easily to SIC 2 digit sectors was an additional advantage. First it meant that economic data on employment, output, trade, etc was readily available, and second, both sectors were already represented in the MDM-E3 model. An important consideration in applying these methods to other sectors will be to consider how the methods might be applied to a cross-cutting sector, such as packaging.

Finally, Defra requested that the quantitative approach developed was submitted as a project deliverable. This final request, in part, lies behind the choice to provide a spreadsheet based framework and apply the MDM-E3 model for comparison. While we believed the MDM-E3 model would be suitable to providing a framework to investigate the complexities resource efficiency savings and their impact, the model is too complex, not to mention large, to submit as a project deliverable. Also, it requires considerable training to become a proficient user of the model and so delivery of MDM-E3 would not even be useful to Defra.

In comparing the results of the two methods it becomes apparent that the sector framework is too limiting a framework to inform policy. While it maintains the advantage of transparency and provides a framework to consider resource efficiencies, it is unable to deal with a number of complexities which could evolve in the wider economy. This would be even more imperative, if we were considering resource efficiencies which arise from substantial capital investments. Plainly, sectors do not operate in isolation and as the very question of resource efficiency is one of supply chains it is vital to consider the interrelationships with other sectors and the wider economy.

By contrast, the whole-economy model is complex and allows for conclusions to be drawn in light of a more comprehensive consideration of the potential impacts. Furthermore, it allows for the interpretation of unintended consequences (an important feature of policy impact analysis). The principal downside of this approach is that it requires a large amount of time and expert use to interrogate and interpret the results of the model, while the sector framework is almost immediately intuitive. Of the two options we would recommend that the advantages of the whole economy modelling approach (complexity, impact on supply industries, labour market interactions, whole economy interactions) considerably outweigh those of the sector framework (simplicity, easy to interpret/use). Especially when we consider some of the main factors we identify as key to the final impacts:

- the positioning of the industry with regard to final product supply chains:
    - resource savings in a highly-connected sector with a long supply chain, like Construction, can transmit larger changes in demand through UK industry than a relatively less-connected sector, such as Food, Drink & Tobacco;

- the import intensity of the resources whose demand is reduced:
    - the economic impacts arising from lower demand for imported inputs to production will be felt overseas, in the economies of trading partners; multiplier effects in the UK will be muted. The extent to which sectors are supplied by overseas suppliers affects the whole-economy impact;

- the type of resource efficiencies, as there may be intra-industry feedbacks:
    - at the level of sectoral disaggregation in the approaches adopted here, sectors often source inputs from 'themselves' ie an input to the production of one unit of Food, Drink & Tobacco product (eg bread production) may have been supplied by another Food, Drink & Tobacco firm (eg flour). In such a case (detailed below in the whole-economy modelling), resource-efficiency savings have two direct demand effects, on both final and intermediate demand; both affect a sector's gross output;

- the price elasticities of demand (and trade demand):
    - the more responsive demand is to prices, the greater the demand and consequent economic effects of lower prices.

- the degree of influence of the business cycle on demand for the sector:
    - that is, the extent to which the economic performance of the UK as a whole affects demand. This is perhaps most clearly seen in the case of Construction, which is a sector that depends greatly on investment expenditure;

- the cost pass-through rate:
    - the size of a sector's supply chain determines the 'upstream' impact, while the extent to which a sector tends to pass savings on through lower prices (as opposed to higher retained profit) is key in determining the 'downstream' impact;

- labour market interactions influenced by the business cycle:
    - the extent to which higher production is met by higher employment rather than a requirement for more hours worked per worker.

Any modelling approach applied to this issue needs to consider most, if not all, of these aspects. That is not to suggest that there aren't other valid approaches to assessing the impact of resource efficiency, at least two other options have desirable qualities. First it would be possible to undertake a detailed panel data investigation at the company level. The main advantage of this approach is the richness of the potential results as it would allow for detailed insight into the way different companies induce resource efficiency and the impact this has. For example, we might see that innovative companies might be in a constant flux of efficiency savings for cost cutting or CSR reasons, while other companies might simply be responding to regulation. This might prove even more important when considering investment led resource efficiencies and broadening the scope to allow for differential competitiveness impacts. Information from our case studies suggests that the driver for resource efficiency savings, might affect the ultimate impact, but we found it difficult to draw a firm conclusion, because of the number of responses we had. The main drawback of this approach is that it requires a wealth of primary data from as many firms within the sector as possible which would require a much more thorough survey of firms to be taken and, furthermore, it requires that firms are able to answer questions on impact resource efficiency savings and differentiate that impact from other impacts occurring at the same time. Our analysis of the responses suggests that this would be at best, a costly undertaking, and at worst, prove impossible to obtain meaningful responses.

Also, the whole economy modelling analysis could be undertaken in a CGE model and in fact, we believe this would give rise to an interesting comparison, particularly when considering resource efficiency which arises from investment. However, it is worth considering that the underlying theory of many CGE models will drive the results of the analysis, and in recent times that theory has come under heavy criticism. To summarise some of these criticisms, CGE models tend to assume that agents are perfectly rational; this implies that they always choose the most efficient outcome. Second, CGE models assume that the world is either in a constant state of equilibrium, or will quickly return to equilibrium, but the events of the credit crisis and subsequent recession illustrate that many markets are often not in equilibrium and in fact, disequilibrium conditions can persist. Third, CGE models assume that a representative agent can be used to represent ‘households’ or an individual sector. This theory has been challenged many times and found not to hold and, in fact, it is clear that companies within sectors can act very differently when faced with exactly the same problem set. Finally, it is difficult to justify an approach to policy which is grounded in theory rather than tested in empirics. Despite all these caveats policy makers should, where possible develop an evidence base from many sources and we would encourage the comparison of CGE modelling analysis with sector disaggregated econometric modelling analysis.

Fundamentally though, the choice of model is arguably less important than ensuring that the data inputs to the modelling process are robust. Our results give an indication of the potential impacts of a variety of savings for two sectors. However, the low response rate to the case studies and the inability of respondents to provide quantitative data means we have less confidence in the results based on these inputs. We believe the Oakdene Hollins inputs may be more robust in this respect, but for future research it will be important to ensure that there is either a robust secondary data source, or that considerable resources are invested in undertaking a full and thorough survey.

Annex A: Data

This Annex sets out the sources for the data used in the estimation of parameters for, and population of, the sector frameworks. Below we describe the main source and any transformations applied to the data to ensure a consistent series of data for each sector. Much of the data is taken from the MDM-E3 databanks, which in turn is derived from official ONS data sources. We have sought to provide a description of the data to allow for transparency and replication of the results.

Table A1.1: Description of Data

Description	Sources	Transformation
Unit cost(£/unit)	Various from ONS and the MDM model	Yes
Producer Prices (2005 = 1)	MM22, ONS	No for FDT and Yes for Construction
Gross Commodity Output(£m, 2005 reference year)	ONS, CE	Yes
Current Price Exports (£m)	MQ10, PB, ONS	No
Current Price Imports(£m)	MQ10, PB, ONS	No
CVM Exports (£m, 2005 reference year)	MQ10, PB, ONS	No for FDT and Yes for Construction
CVM Imports (£m, 2005 reference year)	MQ10, PB, ONS	No for FDT and Yes for Construction
Technological progress (£m, 2005 reference year)	Various sources: ONS, Eurostat and CE	Yes
Industry Wage and Salaries (£m)	Input-Output Supply and Use Tables (IOSUTs), ONS	Yes
Hours worked (h)	Eurostat	No
Male Full Time(000s)	ONS/IER	No
Female Full Time(000s)	ONS/IER	No
Male Part Time(000s)	ONS/IER	No
Female Part Time(000s)	ONS/IER	No
Male Self-Employed(000s)	ONS/IER	No
Female Self-Employed(000s)	ONS/IER	No
Total Employment (000s)	ONS/IER	Yes
Full-Time equivalent employment(000s)	ONS/IER	Yes
Real wages and salaries per Full-Time equivalent employment (£m/000s)	Industry Wage and Salaries (£m),Producer Prices (2005 = 1),Full-Time equivalent employment	Yes
Export price (2005=1)	PB,MQ10,ONS	Yes
Import price (2005=1)	PB,MQ10,ONS	Yes
UK GDP(£m, 2005 reference year)	Blue Book/UKEA, ONS	No
UK household expenditure(£m, 2005 reference year)	Blue Book/UKEA, ONS	No
GDP deflator (2005=1)	Blue Book/UKEA, ONS	Yes
Single Market Dummy (1992-)	CE	Yes

Industry unit cost (£/unit)

The calculation of unit cost is complex and it is deal with in our MDM-E3 model. The unit cost is the sum of the following variables, divided by industry output.

- Unit labour cost (wages and salaries and employers' NI contribution)

- Unit material and service costs (through the input-output framework)
- Unit net tax cost (commodity tax, tax on productions and import duties)

Industry output price (2005=1)

For FDT, it is the four-letter code in the 'POKH' in the MM22 publication from the ONS.

For Construction, it is calculated by dividing the Current price value added data by the CVM value added data ('QTPL' and 'GDQB' from Blue Book, ONS).

Industry gross Commodity Output (£m, 2005 reference year)

ONS stopped publishing CVM industry gross output since 1996. Therefore data for 1996- is estimated by Cambridge Econometrics using the growth rate of value added output and is then made consistent with the ONS supply and use tables.

Industry current Price Exports and Imports (£m)

For FDT, CP export is 'WFGB' and CP import is 'WFVA' from the MQ10 publication from the ONS.

For Construction, CP export is 'FJPI' and CP import is 'FJRA' from the Pink Book from the ONS.

Industry CVM Exports and Imports ((£m, 2005 reference year)

For FDT, CVM export uses 'WFNO' and CVM import uses 'WGCQ' from the MQ10 publication from the ONS.

For Construction, CVM trade data is calculated by deflating the CP data using both the export and import deflators for services. The MQ10 publication only includes both CP and CVM trade data for the agricultural and production sectors. Therefore by taking these sectors out from the total UK CP and CVM trade (from the Blue Book), we are left with total CP and CVM trade for the services sectors. We then calculate the trade deflators for the service sectors.

Industry technological progress

It is derived by using both the industry investment (Capital stock publication from ONS) and R&D (Eurostat) data. The procedure involves specifying a parameter (lambda) which essentially controls the smoothness of the series and is known as a 'decay parameter'.

The idea of the index is that it smoothes out investment as technology changes through the infusion of new equipment and machines. Today's investment will induce an increase in technology but only part of this will have an effect on prices, productivity, etc., while part of the past technology will have an effect too. If lambda is close to zero the decaying process becomes very fast, while if lambda is near to unity, the decaying process is very slow.

Industry Wage and Salaries (£m)

The ONS stopped publishing wages and salaries data since 1996. Therefore the industry total wages and salaries data is extended from old vintage released by the ONS using the industry employment growth. However, we make sure that it is consistent with the industry Compensation of Employees from the Input-Output Supply and Use Tables.

Industry hours worked (h)

Data is taken from Employment and unemployment (LFS) from Eurostat.

Industry Employment (000s)

Cambridge Econometrics receives the processed industry employment data by type from Warwick Institute for Employment Research (IER). IER makes use of the employment data from the ONS and various survey data to process the data. For each industry, we receive data by the following six types: Male Full time, Female Full Time, Male Part Time, Female Part Time, Male Self-Employed, Female Self-Employed.

Therefore total industry employment is calculated by taking the sum of these six types.

Full-time equivalent employment is calculated: (Male Full time+ Female Full Time) + 0.429*(Male Part Time, Female Part Time)

Industry real wages and salaries per Full-Time equivalent employment (£m/000s)

For both industries, we firstly deflate the CP industry wages and salaries using Industry output price to obtain the real industry wages and salaries.

The real industry wages and salaries are then divided by the full-time equivalent employment to get the per employment measure of wages and salaries in real terms.

Industry export and import prices (2005=1)

Nominal export price is calculated by dividing the CP export data by CVM export data.

Nominal Import price is calculated by dividing the CP import data by CVM import data. Therefore, the import price series implicitly accounts for exchange rates and the weighting of prices from changing import sources.

UK GDP (£m, 2005 reference year)

The series is from the Blue Book/UKEA from the ONS. The four letter code is: 'ABMI'.

UK household expenditure (£m, 2005 reference year)

It is calculated by adding two series from the Blue Book/UKEA from the ONS: 'ABNU' for Final Consumption Expenditure of NPISHs; 'ABPF' for Household final consumption expenditure.

UK GDP deflator (2005=1)

It is calculated by dividing the CP gross value added output by the CVM gross value added output from Blue Book/UKEA from the ONS. The corresponding four-letter codes are 'ABML' and 'ABMM'.

Single Market Dummy (1992-)

It is a dummy variable which takes the value of 1 for years 1992 and onwards. It takes the value of 0 for years before 1992.

Annex B: Annex to Results

Table B1: Macroeconomic results in 2015 (%)				
	S1a	S1b	S2a	S2b
GDP	-0.02	0.01	-0.01	-0.12
GDP deflator	-0.14	-0.05	-0.05	-0.14
Household expenditure	-0.01	0.01	-0.01	-0.09
Exports	-0.03	-0.01	-0.01	-0.15
Imports	-0.01	-0.02	-0.01	-0.03
Employment	-0.10	-0.02	-0.03	-0.18

Note(s): Results are reported as percentage differences from the scenarios to the baseline i.e. the economic effects of implementing resource-efficiency savings.

Table B2: Gross Value Added in 2015 (%)				
	S1a	S1b	S2a	S2b
Agriculture	-1.71	0.03	-0.02	-0.13
Coal	0.00	0.00	0.00	0.00
Oil & Gas	0.00	0.00	0.00	0.00
Other Mining	0.00	0.00	-0.01	-0.11
Food, Drink & Tobacco	**5.21**	**1.74**	-0.01	-0.09
Textiles, Clothing & Leather	0.05	0.07	0.00	-0.19
Wood & Paper	-0.14	-0.01	-0.13	-1.68
Printing & Publishing	-0.10	-0.01	-0.08	-0.95
Manufactured Fuels	-0.12	-0.01	-0.02	-0.15
Pharmaceuticals	0.04	0.00	0.00	0.09
Chemicals NES	-0.29	-0.01	-0.05	-0.76
Rubber & Plastics	-2.46	-0.13	-0.48	-5.11
Non-Metallic Mineral Products	-0.08	0.00	-0.20	-3.01
Basic Metals	-0.10	-0.02	-0.06	-0.67
Metal Goods	-0.16	-0.03	-0.14	-1.75
Mechanical Engineering	-0.11	-0.02	-0.04	-0.51
Electronics	-0.21	-0.04	-0.07	-0.57
Electrical Engineering & Instruments	-0.04	0.00	-0.01	-0.18
Motor Vehicles	-0.13	-0.02	-0.04	-0.34
Other Transport Equipment	0.05	0.02	0.00	-0.01
Manufacturing NES	-0.56	-0.06	-0.18	-1.51
Electricity	-0.44	-0.29	-0.13	-0.27
Gas Supply	-0.17	-0.10	-0.06	-0.21
Water Supply	-1.47	-0.20	-0.05	-0.15
Construction	-0.05	-0.01	**0.47**	**1.80**
Distribution	-0.29	-0.10	-0.10	-0.30
Retailing	-0.01	0.00	-0.01	-0.10
Hotels & Catering	0.03	0.02	-0.02	-0.11
Land Transport etc	-0.11	-0.03	-0.05	-0.31
Water Transport	-0.03	0.01	-0.04	-0.35
Air Transport	-0.04	0.01	-0.03	-0.24
Communications	-0.06	-0.01	-0.02	-0.14
Banking & Finance	-0.01	0.00	-0.01	-0.09
Insurance	-0.04	0.00	-0.01	-0.12
Computing Services	-0.06	-0.01	-0.02	-0.15

Table B2: Gross Value Added in 2015 (%)				
	S1a	S1b	S2a	S2b
Professional Services	-0.06	-0.01	-0.02	-0.16
Other Business Services	-0.07	-0.01	-0.02	-0.16
Public Administration & Defence	0.00	0.00	0.00	-0.01
Education	-0.01	0.00	-0.01	-0.06
Health & Social Work	0.00	0.00	0.00	-0.03
Miscellaneous Services	-0.05	-0.01	-0.02	-0.12
Note(s): Results are reported as percentage differences from the scenarios to the baseline i.e. the economic effects of implementing resource-efficiency savings.				

Table B3: Employment in 2015 (%)				
	S1a	S1b	S2a	S2b
Agriculture	-1.17	0.00	-0.01	-0.09
Coal	0.06	0.02	0.01	0.06
Oil & Gas	0.00	0.00	0.00	0.00
Other Mining	0.07	0.03	0.04	0.15
Food, Drink & Tobacco	**-0.49**	**-0.27**	-0.01	-0.08
Textiles, Clothing & Leather	0.02	0.05	-0.01	-0.20
Wood & Paper	-0.30	-0.04	-0.15	-1.59
Printing & Publishing	-0.14	-0.03	-0.06	-0.53
Manufactured Fuels	-0.07	-0.01	-0.01	-0.08
Pharmaceuticals	0.00	0.00	0.00	-0.01
Chemicals NES	-0.13	-0.01	-0.02	-0.30
Rubber & Plastics	-1.77	-0.11	-0.35	-3.72
Non-Metallic Mineral Products	-0.11	-0.02	-0.29	-3.59
Basic Metals	-0.02	-0.01	-0.01	-0.08
Metal Goods	-0.06	-0.01	-0.05	-0.59
Mechanical Engineering	-0.04	-0.02	0.00	-0.01
Electronics	-0.10	-0.02	-0.03	-0.28
Electrical Engineering & Instruments	-0.02	-0.01	0.00	-0.06
Motor Vehicles	0.07	0.02	0.02	0.07
Other Transport Equipment	0.01	0.00	0.00	0.01
Manufacturing NES	-0.33	-0.05	-0.09	-0.77
Electricity	-0.25	-0.15	-0.08	-0.10
Gas Supply	-0.08	-0.05	-0.01	0.05
Water Supply	-0.95	-0.14	-0.04	-0.10
Construction	-0.09	-0.01	**-0.15**	**-0.65**
Distribution	-0.12	-0.04	-0.04	-0.11
Retailing	-0.03	-0.01	-0.01	-0.07
Hotels & Catering	-0.02	0.00	-0.02	-0.09
Land Transport etc	-0.13	-0.04	-0.04	-0.22
Water Transport	-0.04	0.00	-0.03	-0.27
Air Transport	-0.15	-0.03	-0.05	-0.35
Communications	-0.14	-0.04	-0.03	-0.16
Banking & Finance	0.00	0.00	0.01	0.06
Insurance	-0.03	0.00	-0.01	-0.07
Computing Services	-0.06	-0.02	-0.02	-0.13
Professional Services	-0.06	-0.01	-0.02	-0.13
Other Business Services	-0.11	-0.03	-0.03	-0.19
Public Administration & Defence	-0.09	-0.03	-0.02	-0.06
Education	-0.08	-0.02	-0.02	-0.09
Health & Social Work	-0.05	-0.02	-0.01	-0.04
Miscellaneous Services	-0.05	-0.01	-0.02	-0.11
Note(s): Results are reported as percentage differences from the scenarios to the baseline i.e. the economic effects of implementing resource-efficiency savings.				

Table B4: Domestic Prices in 2015 (%)				
	S1a	S1b	S2a	S2b
Agriculture	-0.08	-0.04	-0.02	-0.06
Coal	0.00	0.00	0.00	0.00
Oil & Gas	0.00	0.00	0.00	0.00
Other Mining	-0.14	-0.05	-0.03	-0.10
Food, Drink & Tobacco	**-1.44**	**-0.57**	-0.03	-0.14
Textiles, Clothing & Leather	-0.14	-0.05	-0.02	-0.09
Wood & Paper	-0.26	-0.04	-0.09	-0.84
Printing & Publishing	-0.14	-0.05	-0.02	-0.09
Manufactured Fuels	-0.17	-0.04	-0.03	-0.17
Pharmaceuticals	-0.08	-0.02	-0.02	-0.09
Chemicals NES	-0.03	-0.01	-0.01	0.00
Rubber & Plastics	-0.33	-0.04	-0.07	-0.67
Non-Metallic Mineral Products	-0.05	-0.01	0.00	0.19
Basic Metals	-0.02	-0.01	0.01	0.21
Metal Goods	0.02	0.00	0.04	0.59
Mechanical Engineering	-0.14	-0.05	-0.02	-0.09
Electronics	-0.09	-0.02	-0.02	-0.04
Electrical Engineering & Instruments	-0.14	-0.05	-0.02	-0.09
Motor Vehicles	-0.03	-0.01	0.00	0.02
Other Transport Equipment	-0.14	-0.04	-0.02	-0.09
Manufacturing NES	-0.10	-0.02	-0.02	-0.10
Electricity	-0.07	-0.02	-0.03	0.02
Gas Supply	0.04	0.02	0.02	0.19
Water Supply	-0.14	-0.05	-0.02	-0.09
Construction	-0.09	-0.02	**-0.27**	**-0.91**
Distribution	-0.12	-0.03	-0.03	-0.13
Retailing	-0.07	-0.02	-0.02	-0.09
Hotels & Catering	-0.22	-0.07	-0.03	-0.17
Land Transport etc	-0.14	-0.04	-0.02	-0.09
Water Transport	-0.24	-0.08	-0.04	-0.17
Air Transport	-0.11	-0.03	-0.03	-0.13
Communications	-0.15	-0.05	-0.03	-0.10
Banking & Finance	-0.15	-0.05	-0.03	-0.11
Insurance	-0.07	-0.02	-0.03	-0.12
Computing Services	-0.02	0.00	-0.02	-0.06
Professional Services	-0.04	-0.01	-0.03	-0.13
Other Business Services	-0.07	-0.02	-0.03	-0.14
Public Administration & Defence	-0.15	-0.05	-0.03	-0.10
Education	-0.15	-0.05	-0.03	-0.10
Health & Social Work	-0.14	-0.05	-0.02	-0.09
Miscellaneous Services	-0.05	-0.01	-0.02	-0.10

Note(s): Results are reported as percentage differences from the scenarios to the baseline ie the economic effects of implementing resource-efficiency savings.

Table B5: Gross Output in 2015 (%)				
	S1a	S1b	S2a	S2b
Agriculture	-1.71	0.03	-0.02	-0.13
Coal	0.00	0.00	0.00	0.00
Oil & Gas	0.00	0.00	0.00	0.00
Other Mining	0.00	0.00	-0.01	-0.11
Food, Drink & Tobacco	**0.36**	**-0.07**	-0.01	-0.09
Textiles, Clothing & Leather	0.05	0.07	0.00	-0.19
Wood & Paper	-0.14	-0.01	-0.13	-1.68
Printing & Publishing	-0.10	-0.01	-0.08	-0.95
Manufactured Fuels	-0.12	-0.01	-0.02	-0.15
Pharmaceuticals	0.04	0.00	0.00	0.09
Chemicals NES	-0.29	-0.01	-0.05	-0.76
Rubber & Plastics	-2.46	-0.13	-0.48	-5.11
Non-Metallic Mineral Products	-0.08	0.00	-0.20	-3.01
Basic Metals	-0.10	-0.02	-0.06	-0.67
Metal Goods	-0.16	-0.03	-0.14	-1.75
Mechanical Engineering	-0.11	-0.02	-0.04	-0.51
Electronics	-0.21	-0.04	-0.07	-0.57
Electrical Engineering & Instruments	-0.04	0.00	-0.01	-0.18
Motor Vehicles	-0.13	-0.02	-0.04	-0.34
Other Transport Equipment	0.05	0.02	0.00	-0.01
Manufacturing NES	-0.56	-0.06	-0.18	-1.51
Electricity	-0.44	-0.29	-0.13	-0.27
Gas Supply	-0.17	-0.10	-0.06	-0.21
Water Supply	-1.47	-0.20	-0.05	-0.15
Construction	-0.05	-0.01	**0.01**	**-0.10**
Distribution	-0.29	-0.10	-0.10	-0.30
Retailing	-0.01	0.00	-0.01	-0.10
Hotels & Catering	0.03	0.02	-0.02	-0.11
Land Transport etc	-0.11	-0.03	-0.05	-0.31
Water Transport	-0.03	0.01	-0.04	-0.35
Air Transport	-0.04	0.01	-0.03	-0.24
Communications	-0.06	-0.01	-0.02	-0.14
Banking & Finance	-0.01	0.00	-0.01	-0.09
Insurance	-0.04	0.00	-0.01	-0.12
Computing Services	-0.06	-0.01	-0.02	-0.15
Professional Services	-0.06	-0.01	-0.02	-0.16
Other Business Services	-0.07	-0.01	-0.02	-0.16
Public Administration & Defence	0.00	0.00	0.00	-0.01
Education	-0.01	0.00	-0.01	-0.06
Health & Social Work	0.00	0.00	0.00	-0.03
Miscellaneous Services	-0.05	-0.01	-0.02	-0.12
Note(s): Results are reported as percentage differences from the scenarios to the baseline ie the economic effects of implementing resource-efficiency savings.				

Annex C: Construction Case Studies

C1.1 Overview

The main aim of this study is to:

- identify a method by which the effect of resource efficiency measures implemented by businesses on employment and competition can be determined.

This case study report relates to the second aim of the study, which concerns the testing of the method. Two sectors have been chosen for further analysis on the basis of the following criteria:

- type of environmental impact;
- potential for resource efficiency gains;
- relevance to Defra's policy remit;
- relevance of the sector to the UK economy;
- characteristics of the industry and market; and
- sensitivity to capital investment or capital redistribution.

This report deals with resource efficiency in the construction sector. It begins with an overview of the sector, before identifying the resource efficiency measures implemented by construction businesses. Consideration is then given to key policy drivers, for example initiatives by Defra or other government departments. This is followed by the detailed investigation of several resource efficiency measures with examples from particular companies.

C1.2 Construction Sector in the UK

C1.2.1 **Overview** of the Sector

The construction sector in the UK is assumed to cover all general construction work including (UKCES, 2008):

- site preparation and demolition;
- building of complete constructions or parts therefore and civil engineering (including all types of buildings, bridges, tunnels, pipelines, roads, airfields, sports facilities, water projects, etc.); and
- installation and completion.

The sector employs around 7% of the UK's workforce[23] and makes a significant contribution to the UK's GVA; indeed, it was responsible for 9.2% of the total in 2007[24]. Annual Business Inquiry (ABI) data[25] collected using the UK Standard Industrial Classification (SIC) 2007 system indicate that total turnover for the construction sector in 2008 was £227,613 million. A total of 292,779 firms were involved, contributing to a GVA of £91,199 million. The data for 2003-2007 are shown in Table C1. Note that since these were collected under the SIC

[23] See DTI (2006): Construction Statistics Annual Report.
[24] Source: Department for Business, Innovation and Skills, http://www.berr.gov.uk/policies/business-sectors/construction, viewed on 12th May 2010.
[25] See Office for National Statistics, http://www.statistics.gov.uk/abi/

(2003) system, they are not strictly comparable with the 2008 data. However, they provide an indication of the main trends.

Table C1: Summary of Main Statistics for the Construction Sector, 2003-2007					
Year	Total Turnover (£ million)	Number of Enterprises	Approximate Gross Value Added (GVA) at basic prices (£ million)	Total Employment (average during the year) (thousand)	Total Stocks and Work in Progress – increase during the year (£ million)
2003	150,892	200,546	53,150	1,329	2,246
2004	158,025	209,172	55,636	1,347	2,159
2005	166,312	220,666	63,308	1,393	2,232
2006	175,770	229,181	67,579	1,394	1,228
2007	196,185	240,367	74,656	1,431	2,162
Notes: data are extracted from Annual Business Inquiry and have been collected under SIC(2003). See Office for National Statistics (http://www.statistics.gov.uk/abi/) for further information.					

The construction sector is mostly made up of small firms; however, it should be acknowledged that large firms undertake a disproportionate part of the work by value (UKCES, 2008). An additional point to note about the sector is that the majority of construction staff work full time. Of those employed in construction in 2007, only 4% were part time (UKCES, 2008).

Innovation

According to a 2007 survey conducted by the Chartered Institute of Building (CIOB), the construction industry is one of those least likely to invest in R&D and innovation (CIOB, 2007). Data from the 2008 National Statistics research paper[26] seem to underline these findings. The last available figures for RDI spending of the industry come from 2006. These indicate that the construction industry spent as little as £17m on research and innovation, even though the sector accounted for around 8% of the country's GDP. However, this low level of spending does not fit with the importance which people attach to RDI. The 2006 CIOB survey, which resulted in over 400 replies from medium to senior management, showed that according to 99.8% of respondents R&D was important or very important to the construction industry. Over half of those who responded identified cost efficiency and sustainability as the main drivers of innovation.

The need for innovation within the sector therefore persists. The industry is mainly driven by site based work which requires a new team of people or group of companies for each project. This can prove to be both an advantage and a hindrance. Where innovative solutions are flexible, they can accommodate the ever changing needs of certain projects and fast adoption of new ideas and technology. Such solutions also need to be able to take on board information and knowledge gained from previous projects. Consequently, a framework strategy is appropriate since this allows the lessons and best practices of individual projects to be incorporated.

C1.2.3 Current Situation

The number of workers in the construction sector was anticipated to rise to over 2.8 million by 2011 (Construction Skills Network, 2007). However, this may no longer be the case since the sector is likely to have been negatively impacted by problems in the housing market (UKCES, 2008). Indeed, previous labour shortages are likely to have been reduced by the recession (Migratory Advisory Committee, 2009). Output for the sector as a whole has fallen by around 25% (Nell, 2009).

[26] UK Business Enterprise Research and Development 2008, http://www.statistics.gov.uk/pdfdir/berd1209.pdf

However, it is anticipated that construction will be supported in the medium to long term by the requirement for infrastructure and public works (UKCES, 2008). There will also be the need for the existing housing stock to be updated so that it complies with the latest environmental and energy standards which are presently only applied to new buildings (ibid). Consequently, growth in output is expected to be around 2.0% per annum over the period 2012-2017 (ibid). However, although productivity has been improving, it has recently levelled off with the result that the expected annual increase in productivity is limited to around 1% (ibid). Employment is expected to grow slightly, with an increase of around 175,000 workers by 2017 (UKCES, 2008).

C1.2.4 Future Issues

In the coming years, one of the more significant issues for the sector is likely to be the UK Low Carbon Transition Plan. This has been discussed by the Innovation and Growth Team (IGT), a group made up of representatives from both the construction industry and Government. The initial findings of the Low Carbon Construction IGT suggest that companies in the construction industry have a three-fold task (HM Government, 2010):

- to decarbonise their own business, wherever they are in the supply chain;
- to provide the owners and occupiers of both new and existing stock with buildings that enable them to lead more energy efficient lives; and
- to provide the infrastructure which enables the supply of clean energy and sustainable practices in other areas of the economy, such as transport and agriculture.

The IGT also notes that dealing with carbon reduction means that consideration has to be given to several other factors including air quality, water conservation, efficient use of money and, of most relevance to this case study, resource efficiency (HM Government, 2010). This will involve actions such as greater use of Building Information Modelling (BIM) and similar information technology application which facilitate with improving resource efficiency throughout the whole project life cycle (HM Government, 2010). The construction sector is resource intensive; figures indicate that the industry uses around 420 million tonnes of resources annually (BRE et al., 2007). In addition, around 90 million tonnes of construction, demolition and excavation (CD&E) waste is currently produced each year, with the sector spending £200 million on landfill tax (BRE et al., 2007). Of this total, some of the waste is likely to be unnecessary and a result of over-ordering; around 10 million tonnes of construction products are wasted every year, resulting in costs of £1.5 billion (NetRegs, ND). However, some of the waste will be hazardous. Indeed, Environment Agency data for 2004 indicate that construction and demolition waste was the largest component of hazardous waste in England and Wales (CRW, 2008). Such waste made up nearly 1.7 million tonnes or 32% of the total for that year (CRW, 2008)[27]. It is important to note that the amount of waste produced has been changing with time. Estimates from an ODPM/Environment Agency survey indicate that waste arisings for the demolition and construction sector were[28]:

- 1999: 82 million tonnes;
- 2001: 105 million tonnes; and
- 2003: 109 million tonnes.

Indeed, the East Midlands Construction Resource Efficiency Club notes that the construction sector is the largest single source of waste arising in England[29]. Reasons for this waste

[27] Construction and demolition waste makes up a large proportion of fly tipped waste (CRW, 2008). It is thought that this would decrease if the economics of recycling, demand for recovered materials and the local availability of recovery schemes were improved (CRW, 2008).
[28] Source: Defra Internet site, Waste and Recycling page, http://www.defra.gov.uk/evidence/statistics/environment/waste/alltables.htm
[29] See East Midlands Construction Resource Efficiency Club, http://www.emcbe.com/resource-efficiency.html

include offcuts, unsuitable storage, packaging (26% of waste), over-ordering and project management/programme issues (BRE et al., 2007). It is important to note that some consideration is currently being given to resource efficiency, for example, around 88% of the inert material handled by demolition contractors is already recycled and either used on site or dispatched for sale off site (CRW, ND). However, although the construction sector is said to be at 90% resource efficiency, this means that it effectively wastes one house out of every ten built (Yorkshire Forward, ND). Consequently, the sector as a whole is likely to have many areas where resource efficiency measures can be applied. Further discussion of such measures is given in the next section.

C2 Resource Efficiency Measures

Types of Measure

As noted in the Scoping Report (RPA and Cambridge Econometrics, 2010), the term resource efficiency has various definitions; in this case study it is used to evaluate the quantity of resource inputs consumed in the production of the same or greater volume of resource outputs. Since resource efficiency measures may be undertaken at different timescales, the case study will distinguish between:

- measures introduced and likely to have an impact in the short-term (i.e. the next five years). It is assumed that these can be assessed in a relatively static environment, with no major changes in external factors such as taxes; and
- measures to be assessed over the longer term, i.e. the next 10+ years. This category is assumed to include those measures that involve considerable implementation costs and consequently may have long payback periods.

There will however be a focus on short-term activities since they allow impacts to be assessed whilst assuming that other factors (e.g. price, taxes, etc.) are relatively constant. Where possible, attempts will also be made to distinguish supply side and demand side measures. Supply side measures can be seen as those which relate to resource savings due to more efficient production processes and transportation. In contrast, demand side measures are about resource sufficiency and resultant stabilisation or reduction in demand. Within the construction sector, there is the potential for resource efficiency in many areas including design, procurement, contracts and processes and management systems (BRE et al, 2007). The following sections provide brief details on resource efficiency measures employed by construction firms.

Short-term Measures

Table 2 provides a list of short-term resource efficiency measures which may be implemented. As per the Scoping Report (RPA and Cambridge Econometrics, 2010), the measures are categorised into four groups depending on whether they relate to energy, material, waste or water. Attempts are also made to distinguish supply side from demand side measures.

Table C2: Short-term resource efficiency measures

Category	Measure	Supply or Demand Side
Energy	Turn off equipment and lights when they are not in use and ensure that engines are not left running when vehicles are not required. This can be undertaken by implementing employee education campaigns, for example see Kier Group's KEEP campaign (Kier Employee Environmental Pledge, http://www.kier.co.uk/responsibility/section.asp?Id=1).	Demand
Energy	Implement an employee awareness campaign to encourage energy efficiency.	Demand
Energy	Reduce transport mileage and associated fuel input by sourcing resources from local suppliers where possible. Using local	Demand

Table C2: Short-term resource efficiency measures		
Category	**Measure**	**Supply or Demand Side**
	sources of labour and materials can minimise transport costs (Ciria, http://www.ciria.org.uk/cwr/pointers.htm).	
Energy	Give consideration to transport of materials. For light, high volume materials avoid excessive transport by compacting if possible. For small amounts of materials, avoid excessive transport by bulking up through milk round or return haulage to supplier/storage yard (CRW, 2008).	Demand
Materials	Re-use excavated soils where possible, i.e. attempt to achieve a cut-fill balance. The re-use of excavated soils could yield savings of up to 1.55% of project costs (BRE et al., 2007).	Supply
Materials	Decrease use of virgin raw materials by recycling or re-using salvageable materials (National Platform for the Built Environment, ND). Materials which have been reclaimed include timber flooring and joists, bricks and paving stones/slabs (BioRegional ReClaimed, 2006).	Demand
Materials	Undertake bio-remediation where this is practical. If the land is contaminated, bioremediation can be three times cheaper than removal and disposal of the affected soil (BRE et al., 2007).	Supply
Materials	Have precut materials delivered to site (BRE, NDb).	Demand
Materials	Use of site-won materials should be encouraged over imported materials (Ciria, http://www.ciria.org.uk/cwr/pointers.htm). For example, when a site is being redeveloped, materials processed by demolition contractors will typically be used in the building phase as recycled aggregate (CRW, ND). Where materials have to be sourced from outside the construction site, use locally sourced and recycled materials e.g. aggregate where possible.	Demand
Materials	Reduce the over-ordering of materials (National Platform for the Built Environment, ND).	Demand
Materials	Implement good practice on site, for example through the use of tools and training provided on site by organisations such as WRAP. Good practice could include using information on where materials with higher recycled content can be sourced from with no extra cost (WRAP, Business Plan 2008-2011).	Demand
Materials	Deconstruction rather than demolition should be undertaken to improve the quality, diversity and quantity of site-won materials and ensure that re-use and recycling can be maximised.	Supply
Materials	Store materials on site so as to minimise loss due to damage from damp and rain (Cambridgeshire County Council and Cambridgeshire Horizons, ND).	Supply
Materials	During construction and demolition, audit the materials on site to see if they can be used in the new development or in another development (Cambridgeshire County Council and Cambridgeshire Horizons, ND).	Supply
Materials	Change methods of work, e.g. make just enough mortar (BRE, NDa).	Demand
Waste	Undertake waste segregation on site so that it can be taken to appropriate recycling centres or re-used where feasible. Note that around 88% of inert materials dealt with by demolition contractors are recycled and subsequently used on site or sent for sale off site (CRW, ND). However, due to increased utilisation of Modern Methods of Construction (MMC) and Off Site Manufacturing (OSM), future demolition workers may find that materials are not as readily recycled as at present (CRW, ND).	Supply
Waste	Work towards best practice in site waste management through the use of tools such as BRE's SMARTWaste tools, for example, the SMARTAudit which can be used to identify the type and amount of waste products generated, the processes causing this and the resultant costs (see http://www.smartwaste.co.uk/index.jsp). Note that Site Waste Management Plans (SWMPs) are a legal requirement for all construction projects over £300,000 in England (WRAP, 2009). They aim to improve resource efficiency through ensuring that all waste produced on site is measured and recorded as re-used, recycled, or disposed of (Devon Sustainable Building Initiative,	Supply (if increasing efficiency) or Demand (if decreasing demand for material or energy input)

Table C2: Short-term resource efficiency measures		
Category	**Measure**	**Supply or Demand Side**
	2008). They additionally promote avoiding and/decreasing the creation of waste at source through resource efficient design and construction (Devon Sustainable Building Initiative, 2008).	
Waste	Take up offers of support from initiatives such as the Pathway Towards Zero Waste programme. This aims to change approach to waste in the South East so that there is less dependence on virgin materials, greater energy production from renewable resources and a decreased carbon footprint (see http://www.seeda.org.uk/pathwaytozerowaste/about.asp). The construction sector is targeted as part of the programme which intends to increase the available infrastructure for recycling business waste materials (SEEDA et al, 2008).	Supply
Waste	Implement good practice on site, for example, measure wastage and waste arisings and then compare this with performance standards (WRAP, Business Plan 2008-2011).	Supply
Waste	Ensure that all bags and containers containing raw materials are properly emptied, since not doing so can lead to significant amounts of waste (see Business link www.businesslink.gov.uk).	Supply
Waste	Identify Key Performance Indicators to help improve recycling performance and overall sustainability (Ciria, http://www.ciria.org.uk/cwr/pointers.htm).	Supply
Waste	Ensure the supply chain has the correct systems in place for managing waste, e.g. carry out waste audits before using a new waste contractor (Source: SEEDA, http://www.seeda.org.uk/pathwaytozerowaste/casestudy2.asp).	Supply
Water	Re-use 'waste water' for low grade purposes (Business link www.businesslink.gov.uk). Decrease the total volume of water used for activities such as dust control through conservation and recycling.	Demand
Water	Check pipes and any meter readings regularly, especially in the winter. This ensures rapid detection of any leaks. This is important given that water bills can cost more than 1% of turnover (Business Link, ND).	Demand

Long-term Measures

Long-term resource efficiency measures are presented in Table 3. Again they are classified according to whether they relate to energy, material, waste or water and whether they are supply side or demand side.

Table C3: Long-term resource efficiency measures		
Category	**Measure**	**Supply or Demand Side**
Energy	Ensure investment in new equipment is put towards machines and tools which are more efficient, e.g. choose vehicles which have a higher average mpg.	Demand
Energy	Decrease embodied energy (steel and concrete have especially high levels) through greater use of recycling.	Demand
Materials	Improve the recycled content and recycling potential of construction products and materials (National Platform for the Built Environment, ND).	Supply
Materials	Look for opportunities for reduced resource consumption (RRC) at an early stage in a project, i.e. from design onwards (National Platform for the Built Environment, ND).	Demand
Materials	Work with supply chains to ensure that materials are assessed on an environmental as well as a cost basis (see article on Envirowise guidance on the Building Talk Internet site, http://www.buildingtalk.com/news/enr/enr112.html).	Supply
Materials	Potential for waste materials to be incorporated into concrete, or for the use of pre-stressed concrete to be increased (National Platform for the Built Environment, ND).	Supply
Materials	Greater standardisation and hence predictability of	Supply

Table C3: Long-term resource efficiency measures		
Category	**Measure**	**Supply or Demand Side**
	construction and manufacturing processes has implications for the amount of waste produced. This is shown by offsite manufacturing processes. Developing new products and materials can also lead to decreased resource consumption (but note that such development is time consuming) (National Platform for the Built Environment, ND).	
Materials	Implementation of long term multiple project partnering agreements can lead to more efficient design and construction, thus minimising the production of waste (Ciria, http://www.ciria.org.uk/cwr/pointers.htm).	Supply (if increasing efficiency) or Demand (if decreasing demand for material or energy input)
Waste	Use Key Performance Indicators (KPIs) to ensure minimum wastage rates from designers, contractors and sub-contractors (BRE, NDa).	Supply
Waste	Design – BRE notes that design could play an important part in decreasing waste in the built environment. It comments that resource efficiency needs to be embedded in design decision making to ensure that it is part of the whole process rather than a separate activity. Points to bear in mind include (1) design for deconstruction, repair and refurbishment; (2) avoid design that becomes easily dated/shabby; and (3) specify materials which have lower wastage rates on installation, have a lower hazard content and are fit for purpose and the design life (BRE, NDb).	Supply (if increasing efficiency) or Demand (if decreasing demand for material or energy input)
Waste	Develop more advanced waste minimisation solutions along with recording better baseline data to ensure that progress can be properly measured (National Platform for the Built Environment, ND).	Supply
Waste	Increase the potential for recycling and minimise waste through use of standardized items and movement from process to performance specifications within contracts (Ciria, http://www.ciria.org.uk/cwr/pointers.htm).	Supply
Waste	Working practices and culture: change working procedures so that they include material management. Implement change management techniques such as awareness raising and training. Support and enthusiasm for waste minimisation and recycling initiatives need to come from the top down. Managers need to see waste as an issue for site schemes to work (Ciria, http://www.ciria.org.uk/cwr/pointers.htm).	Supply (if increasing efficiency) or Demand (if decreasing demand for material or energy input)
Water	Decrease leakage from water infrastructure through improved modelling of built assets and leak detection, and through the development of technology which ensures repairs are simple.	Demand

C2.1 Key Policy Drivers

This section looks at the key policy drivers behind the resource efficiency measures. In particular, efforts are made to determine whether the measures can be attributed to existing Defra-led activities or are a result of activities outside of Defra. Brief consideration is then given to the impacts of the resource efficiency measures on employment and competition.

Policy Drivers

There are a range of policy drivers behind the various resource efficiency measures undertaken by the construction sector. BRE et al (2007) note that key drivers for resource efficiency in the construction sector include:

- legislation, in particular the Landfill Directive, the Duty of Care (in relation to the storage and transport of waste and the completion of waste transfer notes), Hazardous Waste regulations and laws relating to fly tipping;

- fiscal measures such as the landfill tax and the aggregates levy; and
- policies including Site Waste Management Plans and the Code for Sustainable Homes, which uses a rating system to indicate the overall sustainability performance of new homes. Central Government procurement policies are also important.

The construction sector is also likely to be impacted by Government strategies. One such example is the DTI Sustainable Development Strategy. This included a section on improving resource efficiency, with a particular focus on reducing greenhouse gas emissions and decreasing waste generation (DTI, ND).

A comprehensive list of legislation and regulations which are currently applicable to the construction sector in England is provided by the Construction Resources and Waste roadmap (CRW, 2008). The aspects which are currently relevant to resource efficiency are summarised in Table 4. This indicates that the Waste Strategy for England has several implications for the construction sector. Objectives for construction waste include (CRW, 2008):

- providing drivers to improve the economic efficiency by creating less waste at every stage of the supply chain;
- encouraging the sector to treat waste as a resource, closing the loop by re-using and recycling more and asking contractors for greater use of recovered materials;
- improving the economics of re-use and recycling by increasing sector demand and securing investment in the treatment of waste.

These objectives can be summarised by the Construction Resources and Waste roadmap (CRW, 2008) as two targets, both with baselines set in 2008:

- Target 1: reduce waste – halve the amount of (non-aggregate) construction waste produced by 2015; and
- Target 2: divert waste from landfill – halve the amount of construction, demolition and extraction waste (CDEW) going to landfill by 2012 as a result of re-use and recycling (excluding materials needed for landfill restoration).

The CRW roadmap also mentions the Strategy for Sustainable Construction. This is a joint industry and government initiative which aims to encourage leadership and behavioural change as well as resulting in benefits for the construction sector and wider economy (HM Government, 2008). The Strategy is based on several points including increasing profitability through the more efficient use of resources (ibid). It has several targets including amongst others (HM Government, 2008).

- to enhance the industry's capacity to innovate and increase the sustainability of both the construction process and its resultant assets;
- by 2012, a 50% reduction of construction, demolition and excavation waste to landfill compared to 2008; and
- that the materials used in construction have the least environmental and social impact as is feasible both socially and economically.

Efforts to reach these targets are likely to involve the implementation of resource efficiency measures. Thus, the Strategy may drive the take up of some measures, in particular those relating to waste segregation, re-use and recycling of materials. Indeed, it is noted that some businesses have already put into place their own waste targets (HM Government, 2008). Regional and local strategies[30] are also likely to affect the implementation of resource efficiency measures. SEEDA (South East England Development Agency) and

[30] Some of the regional policy landscape is subject to change under latest Government plans

several partners have developed the Business Resource Efficiency Support Strategy for the South East. Although this is not solely for the construction industry, the sector is likely to be affected by the following three targets, amongst others (SEEDA et al, 2008):

- reduce carbon emissions by 20% by 2016;
- increase diversion of waste from landfill to 80%; and
- reduce water consumption by 20%.

Movement towards business resource efficiency will be encouraged by SEEDA using a variety of means including (SEEDA et al, 2008):

- overseeing the delivery of the Pathways Towards Zero Waste regional initiative;
- embedding resource efficiency and sustainability throughout its activities including innovation and growth plans and skills programmes; and
- driving sustainable procurement in the public and private sector supply chains.

SEEDA also proposed using existing relationships and support mechanisms to promote the business uptake of measures to save energy, water and waste (ibid). These included encouraging energy and water companies to target businesses with high consumption levels and asking trade and business associations to target members (SEEDA et al, 2008).

Another regional example is given by the development agency One NorthEast, which ran the MIDAS programme from 2006 to 2008. MIDAS was delivered by TNEI Services and provided businesses in the region with expert consultancy advice to help improve resource efficiency[31]. The programme resulted in:

- £15 million of identified energy savings;
- £5 million of implemented savings;
- a reduction of 40,000 tonnes in carbon dioxide emissions; and
- help given to 700 companies in the North East to manage their energy, waste and water issues.

MIDAS worked by providing businesses with a free diagnostic report showing areas where energy, waste and water could possibly be saved. Subsidised consultancy support was then offered if companies wanted to look into these areas, and ultimately make the recommended changes. Although all private sector companies were eligible to take part, the programme focused on those with the biggest issues in terms of resource use and landfill tax. Given the high resource use and waste disposal within the construction sector, it is likely that a significant number of construction firms were amongst those involved.

Implementation of resource efficiency measures within the construction sector is also likely to be driven from the European level by the introduction of the Integrated Pollution, Prevention and Control (IPPC) Directive in England and Wales. This encourages businesses and industry to decrease the impact of their activities on the environment through avoiding or decreasing pollution. Other such influences include the EU Natural Resource Use Thematic Strategy. This aims to develop a framework and measures which enable the sustainable use of resources without detrimental impacts on the environment (CRW, 2007). Since the construction sector uses a large amount of materials, it is likely to have a prominent position within the strategy (CRW, 2007).

[31] Further information on the programme can be found at http://www.tnei.co.uk/pages/case-studies/midas-resource-efficiency-programme.php

Table C4: Summary of Legislation Relevant to Resource Efficiency in the Construction Sector			
Legislation/ Policy Driver	**Details**	**Impact on Construction in 2007**	**Predicted Impacts for Next Five to Seven Years**
Waste Strategy for England 2007 (Defra)	Main objectives include: creation of less waste across the supply chain; closing the loop through re-use and recycling; and improving the economics of re-use and recycling centre. Targets under consultation at time of publication included (1) halving the amount of construction, demolition and excavation waste going to landfill by 2012; (2) construction clients to include contractual requirements for measurement and improvement of materials resource efficiency in half of construction projects valued at over £1 million by 2009; and (3) Government to achieve waste neutral construction in its major construction projects by 2012.	Developing policy and focus for the construction sector and its waste by providing clear targets, milestones and actions. Joined up thinking between Government and industry. Increased diversion of waste from landfill with a focus on the supply chain and Government procurement.	Joint working between Government and industry. Increased diversion of waste from landfill, reduction in amount of waste arising and increased client requirements for resource efficiency. Increased markets for reclaimed and recycled materials.
Draft Sustainable Construction Strategy 2007 (BERR)	Aims to establish a joint government and industry strategy to make a step change in the sustainability of the industry, consulting on the targets within the England Waste Strategy as well as introducing (1) zero net waste at construction site level by 2012; (2) zero waste to landfill by 2020; and (3) halving the amount of construction waste produced at site level by 2015 (new build)	Industry and Government have a shared vision and strategy for sustainable construction including waste. Provision of suitable targets for the industry to carry out effective action.	Manufacturers consider resource efficiency within lifecycles. Integrated supply chains to tackle waste. Designers/architects to specify resource efficiency.
Site Waste Management Plans (SWMPs)	From April 2008, SWMPs are compulsory for projects over £300,000.	Encouraging planning and effective management of waste on site, also reduction in fly tipping	Effective planning, monitoring and management of waste on site through the use of a SWMP. Ongoing reduction in fly tipping.
Code for Sustainable Homes (CSH)	A voluntary code to assist housebuilders to meet minimum environmental standards. A CSH rating is required for all new homes from May 2008.	Require SWMP (as above). Some push towards best practice.	Will be revised to require additional waste reduction and resource and efficiency above those in SWMPs, e.g. targets will be set for waste generation.
Packaging regulations	Companies are obliged to recover packaging waste	Construction industry must comply with the Producer Responsibility Obligations (Packaging Waste) Regulations if they have a turnover of more than £2 million and handle 50 tonnes of packaging waste per year.	Work with supply chains and product manufacturers to reduce waste and ensure packaging is re-usable/returnable.
Landfill tax	Landfill tax for active waste is £32 per tonne from April 2008 *(Note: landfill tax as of April 2010 is £48 per tonne.)*	Increased costs of collection of waste from construction, refurbishment and demolition sites	Significantly increased costs to industry if producing waste and using waste management contractors. Incentives to reduce the amount of waste produced and recycle and recover more waste, making it economically beneficial to do so.
Aggregates Levy	Aggregates Levy is £1.95 per tonne from April 2008. *(Note that the current rate is £2.00 per tonne.)*	There is an economic incentive to use recycled materials and to minimise the use of primary	Increased economic incentive to use recycled and secondary aggregates, including more on-site re-use

Table C4: Summary of Legislation Relevant to Resource Efficiency in the Construction Sector			
Legislation/ Policy Driver	**Details**	**Impact on Construction in 2007**	**Predicted Impacts for Next Five to Seven Years**
		aggregates so reducing environmental impacts. Encouraging the use of recycled and secondary aggregates in low grade applications.	and more procurement/purchasing considerations. Better quality of supply of recycled and secondary aggregates allowing their use in high value applications
Hazardous Waste (England and Wales) Regulations 2005	Pre-treatment of most waste before landfill. Fewer landfill sites accepting hazardous waste. More waste materials defined as hazardous waste.	Increased costs of disposing of hazardous waste to landfill and requirement to establish what wastes are hazardous. If a site produces more than 200kg per year, the company will have to register that site with the Environment Agency. Engaging with the suppliers of products in terms of their hazardousness when disposed of is useful – this could encourage the use of non-hazardous materials. More contaminated sites treated in-situ to avoid removal and disposal costs.	Increased costs for removal of hazardous waste from construction and demolition sites. Encourage designers, contractors and sub-contractors to use materials that are non-hazardous.
Source: information sourced from the Construction Resources and Waste Roadmap (CRW, 2008)			

Developing Policy Drivers

Consideration should also be given to developing drivers, for example those at the EU level. These include (CRW, 2008):

- the possible development of the End of Life Building Directive (where industry will have to take responsibility for houses which it builds, maintains and demolishes, as well as the waste generated at each stage); and
- the EU Thematic Strategy on Waste Prevention and Recycling.

The strategy for the prevention and recycling of waste was proposed in December 2005[32]. According to the Construction Resources and Waste Roadmap (CRW, 2008), it is possible that this will lead to prevention programmes and recycling targets for priority materials, including construction demolition waste. In the medium-term (i.e. the next five to seven years), this is likely to lead to the requirement for more waste from construction and demolition to be recycled, with both on and off site systems put in place to enable this (CRW, 2008).

The construction sector may also be impacted in the future by the Market Transformation Programme[33]. This has been set up by Defra to support Government policy on sustainable products, with the aim of decreasing the environmental impact of products for their whole life cycle (CRW, 2007). The current programme considers construction products as a particular priority, including (CRW, 2007):

- off-site fabricated housing (OSF) and modern methods of construction (MMC) – the strategy is to progress towards systems and products with lower environmental impacts;
- floor coverings – the intention is to quantify measures for impact reduction and to assess opportunities for minimising the amount of flooring waste sent to landfill;
- roofing products – the strategy is to quantify measures for impact reduction and assess the opportunities for decreasing the roofing waste sent to landfill;
- insulation products – work is to include assessing opportunities for decreasing the amount of insulation waste sent to landfill;
- window systems and plasterboard – the aim is to progress with specific actions to decrease waste through both design and manufacture; and
- lighting and comfort cooling – work includes scoping the future waste impact.

There has already been a surge in demand for greener construction products (HM Government, 2008), so it likely that the above research will have impacts for resource efficiency in the future.

Other Drivers and Influences

Drivers are likely to include internal efforts to reduce costs and increase profits (particularly important given the current economic situation), as well as external factors for example more stringent legislation and new policies. External drivers include client requirements such as (BRE et al., 2007):

- desire for improved environmental performance;
- specifying the use of waste monitoring and targets; and
- the use of EcoHomes and BREEAM (BRE Environmental Assessment Method for buildings).

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32 Information sourced from Europa Internet site, http://europa.eu/index_en.htm

33 See Defra's Internet site for further information http://efficient-products.defra.gov.uk/cms/market-transformation-programme/

Clients may even specify particular resource efficiency targets. For example, the tender for the demolition of the Kings Crescent Estate in Hackney requested that as a minimum, 85% of the total quantity of demolition arisings had to be re-used or sent for off site recycling on the project (CRW, ND). The implementation of resource efficiency measures might additionally be driven by public opinion, since customers are tending to look favourably on environmentally friendly companies (Yorkshire Forward, ND).

Aiming for best practice, responding to incentives and working towards self imposed standards are also important drivers (NHBC Foundation, 2007). Initiatives such as WRAP (the Waste and Resources Action Programme), which was set up to promote resource efficiency, run various programmes to encourage the development of stable markets for recycled materials and the removal of barriers to waste minimisation, re-use and recycling (see http://www.wrap.org.uk). WRAP's Business Plan 2008-2011 includes three headline targets which are (WRAP, ND):

- WRAP will deliver diversion from landfill of 8 million tonnes of materials from the municipal, industrial and commercial waste streams;
- WRAP's programmes will deliver savings in carbon emissions of 5 million tonnes of carbon dioxide equivalent; and
- WRAP will deliver around £1.1 billion of positive economic impacts for business, local authorities and consumers, through £850 million of cost savings and £280 million of increased turnover in the recycling and related industries.

The Plan highlights the construction sector in particular as being an area where there are still benefits to be gained through diverting materials from landfill, as well as recycling (WRAP, ND). WRAP's Construction Portal provides advice and information specifically geared towards resource efficiency in the construction sector. WRAP additionally works with both public and private sector clients and contractors to show the business benefits which can be achieved through increasing resource efficiency (WRAP, ND). Another construction specific programme is the Construction Resources & Waste Platform (CRW) (see http://www.crwplatform.co.uk). This is managed by AEA and BRE with funds from the Business Resource Efficiency and Waste (BREW) programme. CRW's main aims are to ensure the construction sector has a say in the allocation of funds to improve resource efficiency, and to improve the understanding of the availability of services and support relating to resource efficiency.

Construction companies have also been offered free advice and support by Envirowise (now part of WRAP) on how to increase profits by minimising waste and their environmental impact (CRW, 2007). Key projects run by Envirowise included (CRW, 2007):

- a pilot study with trade suppliers to develop training materials/approaches for operatives and the supply chain;
- the production of a publication to consider packaging waste on construction sites. The intention was for the guide to be made available for downloading and as a publication with a software tool;
- a scoping study to look at designing for resource efficiency;
- workshops on Site Waste Management Plans;
- waste management training for small builders on site;
- management and provision of advice on environmental supply chain partnerships;
- site visits to provide tailored guidance to help companies save money through waste minimisation and resource efficiency; and
- support and funding for the Resource Efficiency Clubs (REC) programme. These clubs aim to help companies decrease costs through minimising energy consumption and waste production.

Another source of information and drivers for the construction sector is the Construction Industry Research and Information Association (CIRIA). This not-for-profit company is owned by a variety of organisations which represent all aspects of the supply chain for the modern built environment. It incorporates those involved with building, civil engineering, and the transport and utilities infrastructure (ibid). CIRIA undertakes research, produces publications, provides training and operates learning networks to raise awareness and promote sharing and adoption of new ideas, techniques and processes (CRW, 2007). Particular initiatives related to resource efficiency include:

- the Construction Productivity Network – this aims to deliver leading edge thinking and improvement opportunities;
- the Construction Industry Environmental Forum (CIEF) – this aims to improve the sustainability and environmental performance of the sector. It provides a nationwide programme of events, along with site visits to demonstrate sustainability in practice[34]; and
- Buildoffsite, an industry wide campaigning organisation which promotes the use of offsite techniques[35].

Actions and programmes run by initiatives such as WRAP (including Envirowise), CIRIA and CRW are likely to drive the implementation of resource efficiency measures. There may also be voluntary agreements which push for improved standards or provide targets to aim for. For example, the Ashdown Agreement on Plasterboard Recycling was signed in March 2007 by WRAP and the Gypsum Products Development Association (GPDA) on behalf of UK plasterboard manufacturers[36]. The agreement aims to decrease the amount of plasterboard waste sent to landfill and increase the amount recycled. Levels are reviewed each year with progress being measured against several targets. The latest figures indicate that progress is being made, despite the current economic problems. For example, Target 3 is (WRAP, 2009): to increase the take back and recycling of plasterboard waste, for use in plasterboard manufacture, to 50% of new construction waste arisings by 2010.

For the 12 months to the end of March 2009, 20% of new construction waste was recycled for use in plasterboard manufacture (WRAP, 2009). The National Industrial Symbiosis Programme (NISP) was involved with implementing the plasterboard regulations in Northern Ireland. NISP raised awareness of the new legislation as well as introducing companies who would be able to complement each other (NISP, 2010a). For example, MacNabb Brothers, a recycling firm which works with the construction industry, was introduced to Gypsum Recycling Ireland by NISP (ibid). MacNabb Brothers retrieves plasterboard and gypsum from building contractors and civic amenity sites (ibid). Gypsum Recycling Ireland then provide a reprocessing service with waste plasterboard and gypsum being recovered for use in fertiliser, contaminated soil treatment, cement and reformed plasterboard (ibid). A total of 25 businesses have been assisted by NISP's involvement overall, with benefits including (NISP, 2010a):

- £65,000 of additional sales;
- a carbon dioxide reduction of 2,860 tonnes;
- £20,000 of cost savings; and
- 1,000 tonnes of landfill diverted.

The uptake of such voluntary initiatives and standards can be affected by legislation and regulations which are already in place. Indeed, it is likely that demand for such plasterboard recycling services will increase further due to (WRAP, 2009):

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[34] See CIRIA Internet site (http://www.ciria.org/service/AM/ContentManagerNet/Default.aspx?Section=Membership_options&Template=/TaggedPage/TaggedPageDisplay.cfm&TPLID=63)
[35] See Buildoffsite Internet site for further details (http://www.buildoffsite.org/).
[36] Information sourced from the WRAP Internet site (http://www.wrap.org.uk)

- landfill tax: this was increased to £40 per tonne in April 2009. There will be an annual increase of £8 per tonne until at least 2013;
- use of site waste management plans (mandatory for construction projects costing more than £300,000); and
- changes in the guidance for the landfilling of plasterboard waste as of 2009, with identifiable plasterboard waste not being allowed into general landfill.

A similar voluntary measure inspired by WRAP is the Recofloor scheme, founded by the flooring manufacturers Polyflor and Altro and run by Axion Consulting[37]. Recofloor is a vinyl flooring waste take-back scheme, which has collected more than 215 tonnes of vinyl flooring waste since January 2009. The scheme covers the whole supply chain and has more than 30 drop off sites around the UK. Offcuts from safety flooring and smooth vinyl are recycled back into new flooring, whilst uplifted or end of life material is used in the manufacture of traffic calming products.

Uptake of resource efficiency measures may also be affected by internal company targets such as Environmental Performance Indicators (EPIs). A typical EPI considers the volume (m^3) of waste produced per $100m^2$ of floor area (BRE et al., 2007). Key Performance Indicators (KPIs) may additionally be used. A waste based KPI might look at the volume (m^3) of waste produced per £100,000 of turnover (BRE at al., 2007). Such measures can be used to look at both the environmental and economic impacts of implementing resource efficiency measures. For example, during construction of the Knottingley Flood Alleviation Scheme, KPIs were used to encourage the re-use and recycling of materials[38].

Private and collective initiatives are also likely to be contributing towards the uptake of resource efficiency measures. For example, the use of more sustainable construction products is encouraged by One Planet Products (http://www.oneplanetproducts.com/), a not for profit social business which is managed as a member led club. The group helps members with the purchase of environmental construction products, materials and services through negotiating price discounts and providing information[39]. Members benefit from both the negotiated bulk buying price and the expertise and advice provided by One Planet Products.

Size of company may also have an influence on whether resource efficiency is given serious consideration. The construction industry consists of a range of firm sizes, from one-man operations up to large companies with bases in several locations. Anecdotal evidence suggests that there is a relationship between the size of a business or organisation, and the extent to which it implements resource efficiency measures. For large well known organisations, the implementation of resource efficiency measures which bring benefits for the environment could be seen as good for business, especially since consumers are perhaps more environmentally aware than in previous times. Indeed, it is acknowledged that higher energy costs and greater public awareness of the benefits of sustainable buildings mean that use of innovative construction methods is justified (Cyril Sweett, 2006). Resource efficiency measures could be seen as adding value to a contract, particularly if two bidders have submitted similarly priced tenders. As an example, Willmott Dixon has a Sustainable Supply Chain Strategy, whose aims include providing leadership within the industry, ensuring suppliers are aware of the sustainability objectives and being ahead of competitors in the market[40]. All projects are rated according to a 10 point plan to determine how sustainable they are. Two of these points relate to the recycled content by value and the percentage of waste diverted from landfill.

[37] See Building Talk Internet site (http://www.buildingtalk.com/news/axo/axo133.html).
[38] Information sourced from CIRIA (http://www.ciria.org.uk/cwr/cs-knottingley.htm).
[39] Information sourced from the Action Sustainability Internet site (http://www.actionsustainability.com/resources/16/One-Planet-Products-Notforprofit-membersowned-buyers-club/).
[40] See Action Sustainability (http://www.actionsustainability.com/resources/42/Willmott-Dixon--Sustainable-Supply-Chain-Strategy/)

For SMEs within the construction sector, legislation (e.g. the waste disposal regulations) remains the key driver of environmental reform (Revell and Blackburn, 2004). This is an important point given that the industry is biased towards small firms (DTI, 2004). In addition, it should be acknowledged that SMEs are not necessarily covered by legislation in the same way that larger firms are. For example, many of the Government's key policies relating to reducing carbon emissions are only applicable to large carbon emitters and energy users (BIS, 2010). This affects the availability of data on energy and resource use by small firms (BIS, 2010). It also means that there is less external pressure on SMEs to implement resource efficiency measures to decrease energy usage.

Internal drivers for resource efficiency in SMEs are likely to be limited. Staff may lack the time or the means to invest in the development of resource efficiency measures. Even if it is accepted that energy efficiency and waste minimisation reduce costs, whether SMEs employ such measures is dependent on the short term investment in time and effort necessary to instigate the change (Revell and Blackburn, 2004). SMEs are also in a different position to larger companies in terms of supply of materials. SMEs may be offered materials at different costs to large national procurers simply because for the former, supply chains are more limited and economies of scale cannot be applied as easily (Cyril Sweett, 2006). This may affect the ability of SMEs to source and use sustainable materials, since environmentally responsible materials sometimes carry a slight premium (Cyril Sweett, 2006). However, in such cases, initiatives and government programmes can help SMEs to develop an environmental policy, or implement resource efficiency measures. For example, Cornwall Glass and Glazing[41] is a family owned business located in St Austell. It was established in 1998 and currently has several branches in both Cornwall and Devon, employing over 100 staff. The company received help from Envision, the South West environmental support programme, who[42]:

- carried out a waste audit to show where there were opportunities for improvement through segregation, recycling and minimisation;
- provided a detailed energy survey and helped with the development of energy management policy; and
- provided energy management awareness training for staff.

As a result of the above actions, the company has:

- decreased annual waste costs by more than £8,000 through a new contract with a local company along with improved waste management procedures;
- ensured that 64 tonnes of waste glass which are produced each year are now re-used or recycled by a local company;
- decreased the amount of waste going to landfill by 84 tonnes per year through improved segregation and recycling; and
- decreased electricity consumption by having a new energy management policy.

This example shows that it is possible for SMEs to actively decide to implement resource efficiency measures themselves. They may be encouraged to do so by initiatives such as the Regional Environmental Review Tool (RERT). This was set up as part of the Resource Efficiency East (REE) Programme to help SMEs in the East of England[43]. The project involved the development of an internet based self help tool which aimed to ensure that SMEs were aware of their energy, water, waste, materials and transport usage, and what actions they could take to improve their environmental performance. In addition to the internet tool, the programme also provided some tailored support.

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[41] See http://www.cornwallglass.co.uk/

[42] Information on Envision and support offered to Cornwall Glass and Glazing can be found on Envision's Internet site (http://79.170.40.235/envisionsw.org.uk/clients.php)

[43] Information on RERT sourced from Pro EnviRo's Internet Site

Where SMEs are contracted out by larger businesses, there may be external pressure on SMEs to implement resource efficiency measures. This is particularly likely where the larger businesses have made a commitment to look at resource efficiency (or even sustainability) along their whole supply chain. Such a commitment would likely involve consideration of not just the impact of a specific material or item during the construction process, but the whole life cost of materials used. The whole life costs have been defined as those associated with the maintenance, replacement and repair of an item, as well as any management and utilities costs over a set period or life cycle (Cyril Sweett, 2006). Obviously, once whole life costs are considered as opposed to just construction related costs, this might favour materials which are the longest lasting, as opposed to those which are the cheapest or have the highest recycled content.

Where construction businesses do manage to innovate and implement resource efficiency measures which save money, it is likely that this saving is then built into their next bid to ensure that the contract is won, rather than using the saving to increase profits. Indeed, some low environmental impact solutions to the problems of energy provision, waste water disposal and general waste recycling have developed as a result of attempts to save energy costs (NHBC Foundation, 2007). However, it is important to note that the development of such technology may also be influenced by practicalities, for example, connecting to the mains at a remote site may be difficult and expensive (NHBC Foundation, 2007).

C2.2 Impacts of Resource Efficiency Measures

The resource efficiency measures driven by the above policies and other influences (e.g. client demand) are likely to be impacting employment and competition. The effects of the resource efficiency measures can be investigated through consideration of their impacts in three areas:

- costs and prices: savings may result from supply or demand side resource efficiencies. For example, on the supply side, re-using materials sourced from the demolition of old buildings is an efficiency measure which avoids the need to purchase new material. Considering the demand side, if equipment, tools and lighting are turned off when not required, this decreases the demand for energy. As noted in the original proposal for this study, such savings offer businesses a range of opportunities including reducing the prices of goods (and so potentially stimulating demand), increasing the output or retaining greater profits;
- competitiveness, GVA, profitability and innovation: note that reviews of the literature have indicated that the relationship between resource efficiency or improved environmental performance and competitiveness is not clear cut; and
- employment and skills: as noted in the scoping report, if resource savings are used to maintain or increase competitiveness with rival businesses, there may not really be any impact on employment, even where price reductions stimulate demand. There may just be a change in an employee’s tasks or responsibilities. Resource efficiencies may even lead to loss of jobs if a particular role is no longer necessary.

C3. Selected Resource Efficiency Measure 1: Waste Segregation and Reuse

The construction, demolition and excavation sector is the largest generator of waste in the UK and at the same time has an approximately 10% share in the GDP. The construction process alone uses over 400 million tonnes of solid material resource[44] and generates over 60 million tonnes of waste each year. This amount is being generated at every stage of a regular construction project, from initial winning of resources such as aggregate, through

[44] Waste Strategy for England 2007, Defra

processing, packaging, transport, use on site, repair and disposal. With the introduction of the landfill tax, waste disposal has become a costly habit especially with the increasing number of materials classified as hazardous. However, in England, around 25 million tonnes of construction, demolition and excavation waste is still sent to landfill each year (Defra, 2008).

According to the Site Waste Management Plan Regulation of April 2008 all construction projects costing over £300,000 in England have to prepare and adhere to a site waste management plan (SWMP) covering amongst other things the amount and type of waste and its projected use. The aim of SWMPs is to decrease the volume of waste produced, encourage re-use and recycling, and strengthen the duty of care requirements for those involved in dealing with construction, demolition and excavation waste (Defra, 2008). The developer/main contractor has to take on a mentoring role and assure suppliers adhere to their environmental policies and have an understanding of waste management practices.

Many waste minimisation measures cost nothing but can lead to big results (Yorkshire Forward, ND). The principle of waste segregation is that contractors can realise financial benefits through removing potentially re-useable materials from the waste stream. Therefore waste segregation and subsequent recycling or re-use is a resource efficiency measure which has the potential to bring short-term benefits in the form of both reduced disposal costs and decreased input costs. The true cost of waste includes the price of the product purchased, transportation, handling, storage and disposal as well as the loss of income that comes from not re-using these materials. Indeed, when costs relating to the original materials, any treatment, energy usage and wasted labour are taken into account, the real cost of waste can be five to 20 times the cost of disposal (Yorkshire Forward, ND). It should be noted that a systematic waste minimisation programme could save a company 1% of its annual turnover (Yorkshire Forward, ND).

C3.1 Example 1: Kier

The Kier Group is a construction, development and service group which specialises in building and civil engineering, support services, public and private house building, property development and Private Finance Initiative (PFI) (see http://www.kier.co.uk/default.asp). With an annual revenue of more than £2.1 billion, the company employs over 11,000 workers around the world. The construction division consists of regional contracting, major building projects (through Kier Build), and the infrastructure and overseas business (Kier Construction and Kier Caribbean & Industrial).

The Kier Group's environmental statement which is published on its website (see http://www.kier.co.uk/responsibility/enviro1.asp) includes the following points of particular relevance to this study:

- the efficient use of materials and resources with particular regard to the long-term sustainability of consumable items;
- minimising the need to travel but where travel is unavoidable, consider taking the least environmentally damaging mode of transport;
- the establishment and maintenance of management structures within its operating companies and divisions with specific responsibility for the implementation of environmental policy; and
- the establishment of targets against which to measure the improvement in environmental performance in key areas, including energy use and waste.

The construction division of Kier calculated that the size of its carbon footprint for 2008 was 26,727 tonnes, which equated to 18.4 tonnes of CO_2 per £million of revenue[45]. It

[45] Information on Kier Group is sourced from the company's website, www.kier.co.uk

subsequently set targets to decrease emissions from energy used to heat, light, cool and power both temporary and permanent offices by a minimum of 10% over the next three years. The construction division also intends to cut the amount of construction waste being produced and the percentage sent to landfill by 20% per year over three years. Use of the SMARTWaste tool developed by BRE indicates that the division currently recycles 21% of its waste, re-uses 31%, recovers 8% and sends the remaining 40% to landfill.

Other resource efficiency measures include the Kier Employee Environmental Pledge (KEEP) campaign, which encourages staff to put their commitment to the environment into practice, for example through making sure they turn lights and computers off at night. Kier is also involved with the WRAP campaign to decrease construction waste. The company has signed the ‘Halving waste to landfill’ initiative and participated in a pilot scheme investigating the benefits of Materials Logistics Plans (MLP). Use of this system at Carmel College in St Helens decreased the percentage of waste sent to landfill to less than 0.5% and cut CO_2 emissions by more than 40 tonnes as well as achieving cost savings.

Kier has worked with Marriott Construction on a Resource Efficiency Pilot Project for the EDS Wavendon Campus Redevelopment in Milton Keynes. Waste segregation was a feasible resource efficiency measure for this development because (EMCBE, ND):

- the site was of sufficient size to allow a waste segregation area to be set up;
- the Project Manager and team were motivated and recognised that benefits could be gained from recycling;
- there was a Gateman on site who was able to monitor site traffic, thus ensuring that subcontractors used skips correctly; and
- other involved companies were also committed to the initiative – Shanks transported the waste to the recycling depot in segregated skips (note that cut pipework was given to a hamster farm), whilst Yorkshire Waste Management segregated the material. Although the latter did take some waste to landfill, it provided a monthly audit of this. It also offered a site induction to site operatives as well as a poster campaign.

C3.2 Example 2: Wates Group

Wates Construction, a UK wide contractor, is part of the Wates Group. In 2009, turnover for the Group as a whole was £945 million, whilst the construction branch recorded its fifth successive year of profit growth, with operating profits increasing to £42.5 million [46]. The company has taken various measures to limit its impact on the environment; many of these relate to resource efficiency. Measures include[47]:

- implementing ‘Target Zero’, the public commitment which aims to eliminate the sending of non-hazardous waste to landfill by 2010. Since the inception of Target Zero, the Group has increased the amount of waste diverted from landfill from 66% to 81%. The use of Site Waste Management Plans has helped achieve this decrease. For example, at a site in Liverpool, an ‘Envirowash’ station was installed to enable paint residue from tools and cans to be filtered and separated into liquids and solids. The solids were subsequently taken by Dulux and re-used in new paints. Target Zero is not limited to on-site work since both suppliers and customers have been informed about the commitment. Wates Group even hosted a six month fast track programme to help eight of its suppliers to develop environmental management systems (EMS). These suppliers all completed the programme and saved approximately £4,000 in comparison to traditional EMS routes. Wates Group has

[46] Source: http://www.wates.co.uk/about/financial
[47] Source: Business in the Community, http://www.bitc.org.uk

also worked with WRAP on leading two demonstration projects on waste minimization and management;

- taking advantage of a manufacturer take-back arrangement, Wates has diverted 488 tonnes of plasterboard from landfill back to British Gypsum for recycling into new boards;
- dealing with resource efficiency on a site-by-site basis. For example, better waste management planning on one of the company's London projects improved recycling efficiency and cut waste costs by 30%. At a Manchester site, cooperation with a local waste management contractor ensured that a segregation yard was built. This led to a 37% reduction in the volume of waste whilst waste costs decreased by 30%. The venture also led to monetary savings of £20,000 per year as well as the provision of additional employment for the local community;
- improving energy management through a project with the Carbon Trust. This helped the company to decrease its energy usage by 10% over six months; and
- putting into place sustainable travel policies. This has led to a decrease in the average number of tonnes of carbon dioxide emitted per employee from 7.12 to 6.35 per year.

C3.3 Example 3: Willmot Dixon

Willmott Dixon Construction is one of the UK's largest privately owned construction firms. The company employs over three thousand people and has posted a turnover of £838 million in 2008; in the same year 213,166m^3 of construction, demolition and excavation waste left the company's over one hundred sites.

Willmot Dixon is aiming to reach its zero landfill policy by 2012 by reorganizing its waste management practices[48]. Having concluded an assessment into the costs of waste handling, the company has found the largest cost to be that of disposal. Consequently it implemented – with the involvement and training of the staff - Site Waste Management Plans (SWMPs) to provide a structure for systematic waste management.

The company has established and emplaced a waste monitoring system to identify the amount and type of waste being sent to landfill and as a result has been able to divert 72.2% of waste previously sent to landfill. Involving the contractors and carrying out regular audits have further reduced the amount of waste sent to landfill.

A waste segregation initiative on site – which included segregating plasterboard waste by stacking offcuts close to the workforce, enabling the offcuts to then be easily selected and used, rather than a new board being cut – has resulted in plasterboard representing only 20% of the waste from site, compared to the 30-40% industry average for college projects. Recycling was also included as old vinyl has been used for new flooring as well as for traffic cone bases.

The company aims to extend its environmental policy to all of its contractors by asking them to provide monthly scores on their sites' impact on the environment. A minimum score of seven out of ten is expected to be achieved each month, with a score below this requiring one of Willmott Dixon's environmental managers to visit the site to discuss and resolve any issues.

C3.4 Example 4: Construction of a Plant Growth Facility

Various resource efficiency measures were employed during the construction of the Plant Growth Facility for the University of Cambridge Department of Plant Sciences

48 See Pathway to Zero Waste, Case Study: Willmott Dixon's Pathway to Zero Waste (http://www.seeda.org.uk/pathwaytozerowaste/casestudieslist.asp)

(Cambridgeshire County Council and Cambridgeshire Horizons, ND). Measures to reduce construction waste included (ibid):

- ensuring the majority of the facility was pre-fabricated off-site;
- replacing 40% of the cement content in the floor slab and concrete foundations with blast-furnace slag (this both reduced carbon dioxide emissions and made use of a waste product); and
- using recycled tyres to create a retaining wall around the external mechanical plant.

The building subsequently achieved a 'Very Good' status as a result of an environmental life cycle impact assessment based on the BREEAM method (Cambridgeshire County Council and Cambridgeshire Horizons, ND).

C3.5 Example 5: Brighton and Hove Wood Recycling Project

The Brighton and Hove Wood Recycling Project was initiated in 1998 to help to limit the amount of wood which was being wasted by the construction sector[49]. Wood is collected from construction sites and sorted according to a simple classification system:

- Grade 1: wood which is good enough for DIY;
- Grade 2: wood which is sound but generally too small for DIY. However, it may be suitable for other uses such as art and craft items and furniture making; and
- Grade 3: this wood represents about 80% of the wood waste stream. This is typically bagged and sold as heating fuel, or given to local farmers who have wood fired greenhouse heaters.

Only around 15% of the total wood collected is discarded due to severe contamination with creosote or other preservatives. The project has an annual turnover of £110,000 (2000-2001 figures) which indicates that it is economically viable to segregate and re-use wood from the construction sector.

C4. Selected Resource Efficiency Measure 2: Re-use of Materials

The re-use of materials from demolition or as a result of site operations (e.g. excavations) can lead to benefits for the environment as well as cost savings for the construction industry. Where demolition is taking place before a site is redeveloped, a pre-demolition audit can be instrumental in identifying what materials can be re-used or sold on. With resource re-use, savings may result from decreased resource inputs, lower transport costs and decreased disposal costs. For example, during construction of Hampshire County Council's Zip Bus Priority Corridor, 3,946 tonnes of material were diverted from landfill (Pathway to Zero Waste, ND). This resulted in savings on landfill tax and new materials of nearly £87,000 (Pathway to Zero Waste, ND). Re-using materials can therefore have a considerable impact on the overall costs. Further examples of where this resource efficiency measure has been implemented are given below.

C4.1 Example 1: Rydon

Rydon is a construction, development, maintenance, investment and management group which works in southern England in a range of sectors related to the built environment (see http://www.rydon.co.uk/). It was established in 1978 and currently employs around 600 people. It has several divisions including Rydon Construction, Rydon Homes and Rydon Maintenance. Rydon has produced a 'Resource Efficiency and Materials Policy' (available

49 Further details on the study can be found on the CIRIA Internet site (http://www.ciria.org.uk/cwr/cs-brighton_wood.htm).

from the company's Internet site) which lists a range of measures which it undertakes to improve environmental performance. These include:

- sourcing materials from within the local area of its operational sites;
- minimising the production of waste and re-using and recycling materials wherever possible; and
- sourcing of aggregates from suppliers who are able to provide locally sourced and recycled materials in accordance with WRAP protocols.

The company also has sustainability and environmental policies in place. Relevant aspects of the latest environmental policy (produced in 2009) include:

- minimising the production of waste arising from company activities;
- minimising energy use;
- minimising water consumption;
- incorporating all environmental considerations into design and promoting energy efficiency;
- promoting the use of recyclable and renewable materials; and
- a commitment to contributing to halving the amount of construction, demolition and excavation waste going to landfill by 2012 (in association with WRAP, the Waste and Resource Action Programme).

An example of resource efficiency in practice is given by construction work undertaken at Bishop Ramsey School, Ruislip. At this site, several resource efficiency measures relating to the re-use of materials were employed[50]. Spoil from other construction activities on the site was used to level the playing fields so that they fulfilled the requirements of Sport England. In addition, material from elsewhere on site was re-used as a base underneath the parking areas. These measures contributed to cost savings as well as decreasing the need for transport and use of new materials and reducing the amount of waste disposed of in landfill.

C4.2 Example 2: Flood and Coastal Risk Management, Brighton

Flood and coastal risk management at Brighton necessitated the complete renovation of the existing defences, with work including (Ciria, ND[51]):

- the encasement of the front face of the existing seawall;
- the removal and replacement of the bullnose;
- the raising of the promenade; and
- the replacement of the rear splashwall.

Since removal of the old structures would result in the need to dispose of a considerable amount of material, efforts were made during the planning stage to determine how the old materials could be re-used. Three opportunities were identified including:

- some of the larger sections of the bullnose could be used as secondary aggregate under the new rock armour revetment (thus avoiding the need to import granite armour from Norway);
- some of the concrete blocks and friable no-fines concrete from the rear of the existing splashwall could be utilised as fill material for the two box structure ramps linking the

50 For details see Rydon's Internet site, in particular http://www.rydon.co.uk/corporate/csr/case-studies/sustainable-design-and-the-promotion-of-resource-efficiency (viewed 17th May 2010).

51 See Ciria Internet site, http://www.ciria.org.uk/cwr/cs-brighton_marina.htm.

promenade and foreshore. Such fill is necessary to provide weight and so prevent the structures moving under wave loading; and

- use of crushed concrete blocks to raise the promenade by 600mm, thus ensuring that the anticipated sea level rise is taken into account.

C4.3 Example 3: National Industrial Symbiosis Programme (NISP)

NISP is a business led initiative which helps develop links between organisations from different sectors with the aim of creating sustainable commercial opportunities and improving resource efficiency (CRW, 2007). The tools used include training, synergy workshops, an Internet based database, company visits and regional events (ibid). The programme covers energy, water expertise, logistics, capacity and materials and is not limited to any particular resource (CRW, 2007). Consequently, it can provide several examples where resource efficiency measures have been implemented. Two construction related examples are described below.

A video production company called Spectrecom needed construction materials for their new studios in Waterloo (NISP, 2010b). Ideally, the company wanted reusable materials to minimise the environmental impact (ibid). Meanwhile, Laing O'Rourke was obtaining large amounts of insulation off-cuts from work on the re-development of Pembury Hospital PFI (ibid). This material was being segregated by Multi Services Kent (ibid). The options for disposal of the insulation included sending it to landfill, or back to the manufacturer (ibid). The latter would be reasonably expensive given that the insulation would have to be transported over a considerable distance (ibid). Due to NISP's involvement, the insulation was actually given to Spectrecom for direct re-use as insulation (ibid). This resulted in cost savings of £6,000, as well as the diversion of materials from landfill and a reduction in carbon dioxide emissions (NISP, 2010b).

In Northern Ireland, the Patton Group was working on several projects in and around the Ballymena area (NISP, 2010c). These projects included the excavation of around 2,500 tonnes of materials which would normally have been disposed of in landfill at a cost of around £15,000 (ibid). NISP introduced the Patton Group to Braidwater Ltd, since the latter was working on a site in Ballymena where levels needed to be raised (ibid). Following an agreement between the two companies, material from the Patton Group sites was transported to the Braidwater site (ibid). This arrangement resulted in economic and environmental savings including (NISP, 2010c):

- the diversion of 2,560 tonnes of waste from landfill;
- £6,400 in additional sales (from gate fees);
- £7,680 in cost savings; and
- the retention of two employees by the Patton Group (they were involved with transporting the excavated material from the Patton sites to the Braidwater sites).

C4.4 Example 4: M4 Junction 13 Improvement Project

This £38 million project was undertaken for the Highways Agency in 2003 and 2004 by Costain Ltd, Mott MacDonald, RPS Planning Transport & Environment and Gifford WSP[52]. The project achieved a 50,000 tonne reduction in primary material requirements through implementing a variety of resource efficiency measures including:

- developing and implementing a project specific Waste Management Plant to ensure that waste streams were identified, recorded and dealt with in a suitable way;
- undertaking in-situ soil stabilisation to decrease the need for virgin aggregate;

[52] For details on the project, see CIRIA (http://www.ciria.org.uk/cwr/cs-chieveley.htm)

- using recycling demolition rubble (from a local supplier) instead of virgin aggregate,; and
- ensuring that 100% of the redundant carriageway was recycled by crushing and screening for use in the new carriageway. This led to savings in terms of decreased Landfill Tax.

These measures were driven by internal company policy, the environmental management system (EMS) and the various cost savings which would result from avoiding the aggregates levy and decreasing the liability for waste disposal costs such as landfill tax. Compliance throughout the project was monitored by weekly environmental site inspections. These covered checking that the Waste Management Plan was being adhered to and materials were being stored and segregated correctly.

C5. Selected Resource Efficiency Measure 3: Sustainable Construction Methods/Design

Sustainable construction techniques entail all water, renewable energy and energy efficiency techniques used during construction or included in new and existing developments. Such techniques are likely to be promoted by Government policies such as Zero Carbon New Homes and Zero Carbon New Non-Domestic Buildings. These aim to ensure that all new homes and non-domestic buildings have zero net annual carbon emissions from 2016 and 2019 respectively (Devon Sustainable Building Initiative, 2008). Note that work is also being undertaken to identify measures and options to improve the sustainability of existing buildings, with particular emphasis on their energy and water efficiency (Devon Sustainable Building Initiative, 2008).

Sustainable construction incorporates all environmentally friendly construction methods including waste minimization, reduction of pollution and mitigation of noise impacts. Examples of sustainable practice are widespread and include measures such as the re-use of crushed aggregates on site, use of solar panels, harvesting of rainwater for flushing toilets, use of ground energy for heating, and sewage treatment by reed beds. Specific examples are given in the following sections.

C5.1 Example 1: Birse Civils

Birse Civils (part of Balfour Beatty Group Plc) is a civil engineering company which provides a range of construction services throughout the UK (see www.birsecl.co.uk). It has around 790 employees (including site based staff) and an annual turnover of more than £270 million. It undertakes both public and private projects ranging in value from £0.5 million to £90 million. The company's work covers the whole construction process from feasibility through to building and maintenance.

As noted by Action Sustainability[53], Birse Civils has undertaken a range of actions related to sustainability, some of which could be classed as resource efficiency measures. Relevant actions include:

- the spending of over £2 million on recycled materials in 2007-08. This saved 4,121 tonnes of CO2, diverted 2,128,920 tonnes of waste from landfill and generated cost savings of £5,322,300. The company was the first civil engineering firm to join the Buy Recycled Code from Envirolink Northwest; and

- work undertaken on the Eaves Green Link road for Lancashire County Council. This project included the construction of 1.45km of single carriageway and a cycle lane in

[53] See http://www.actionsustainability.com/resources/33/Birse-Civils/

Chorley. Local companies carried out 81% of the construction work and over 84% of construction materials (by value) contained recycled elements. In addition, 6000 wagon journeys were removed from local roads.

C5.2 Example 2: Circle 33 Housing Trust

Circle 33 Housing Trust (part of Circle Anglia) aimed to build a housing development in Cambourne which had reduced carbon dioxide emissions (Cambridgeshire County Council and Cambridgeshire Horizons, ND). This was achieved by employing a variety of measures relating to both design and construction including (Cambridgeshire County Council and Cambridgeshire Horizons, ND):

- using materials from sustainable sources;
- considerable reliance on off-site manufacture;
- significant use of timber frame and light gauge steel (clad externally with a mixture of traditional brickwork through colour render and Canadian red cedar);
- for a large proportion of the houses, insulating them to a high standard, installing high efficiency condensing boilers, solar hot water exchangers and photo-voltaic panels, and ensuring they have whole house heat recovery systems, along with the ability to export electricity back to the national grid when generation is greater than demand;
- for the other houses in the development, the use of passive stack ventilation systems; and
- use of water butts to enable rainwater collection.

Although not all of these measures are directly related to resource efficiency during construction, it is clear that some are, for example, the use of materials which have been sustainably sourced and the reliance on off-site manufacture. This example shows that resource efficiency measures within construction may sometimes be part of a wider drive for sustainability or the reduction of carbon emissions throughout the life of a development. Therefore, resource efficiency measures and their impacts cannot necessarily be considered in isolation.

C5.3 Example 3: SmartLIFE Business and Training Centre, Cambridge

The construction of this business and training centre began in 2005 (SECURE, ND). Since the project aimed to ensure that consideration was given to sustainability, the materials used included (SECURE, ND):

- recycled newspaper insulation;
- PVC coated cotton as a roof fabric;
- wall clad with aluminium sheets;
- timber-based internal floors, external walls and roofs;
- roofing insulation is CFC free polyurethane foam; and
- windows and doors are made from FSC-certified timber.

To ensure waste production during construction was reduced, several different Modern Methods of Construction (MMC) were employed including use of a timber frame open panel system along with solid timber panels and composite panel roofing (Cambridgeshire County Council and Cambridgeshire Horizons, ND). In addition, space was earmarked for recycling bins to minimise site waste (Cambridgeshire County Council and Cambridgeshire Horizons, ND).

As with the previous example, this construction project shows that resource efficiency measures applied during the actual construction process itself are often implemented in tandem with other measures or as part of an overall programme to reduce the environment impact of a development. In this particular instance, the impact during operation was considered in addition to the impacts of the actual construction process. However, there is a caveat in relation to the use of MMC. The NHBC Foundation (2007) reports that no studies have been undertaken to determine the impact of MMC on waste generation. Although manufacturing and assembling the products off site supposedly means that any waste produced can be dealt with (i.e. recycled, re-used, etc.) more easily, MMC could lead to an increase in certain waste streams such as packaging (NHBC Foundation, 2007).

C5.4 Example 4: Simons Construction

Simons Construction is a privately owned property solutions company which employs around 350 people[54]. The company has implemented an environmental policy along with a staff training programme[55]. It is also working with stakeholders and sector organisations to raise awareness of issues such as waste minimisation, segregation and recycling. The company has been particularly successful in reducing construction waste, with a two thirds reduction in waste tonnage on its best performing site in 2004. Particular efficiency measures include[55]:

- greater efficiency with the use of materials on site – this ensures fewer materials are purchased, thus resulting in knock-on impacts for vehicle movements. A decrease of 1,500 tonnes in the amount of materials used has led to savings of £100,000 in terms of disposal costs; and
- employing a five skip waste segregation system – this has led to a 65% reduction in waste volume against average.

C5.5 Example 5: Marshalls PLC

Marshalls Group manufactures natural stone and concrete hard landscaping products to supply the construction, home improvement and landscape markets[56]. It operates several quarries and manufacturing sites within the UK. The Group's Environmental Policy includes the following aims amongst others[56]:

- to reduce the volume of mains and extracted borehole water to 0.05m^3 per ton of production by 2012;
- to reduce the weight of packaging per tonne of production by 3% per annum over a 3 year cycle to a level where pack and product safety is not compromised; and
- to reduce the % of total waste to landfill per production output by 3% per annum on a 3 year rolling average.

Savings thus far include[57]:

- avoiding 4,000 vehicle journeys and improving fuel mileage by 20%. This gave a reduction of 1,463 tonnes of CO_2 per year;
- reducing the amount of waste generated by 44% between 2003 and 2006. In addition, £180,000 in revenue was created in 2006 through the recycling of waste materials;
- reducing packaging at Marshalls' Brookfoot site. This reduced the amount sent to landfill from 1,200 tonnes in 2001 to 4.6 tonnes in 2006, saving £5,000 in landfill costs and leading to additional profit of £8,000;
- recycling dust from manufacturing back into aggregates at Brookfoot. This saved £41,000 and 2,500 tonnes of landfill annually; and

[54] Source: http://www.simonsgroup.com/SG-Home/SG-AboutUs.html
[55] Source: Business in the Community, http://www.bitc.org.uk/resources/case_studies/afe_env_05_simons.html
[56] Source: http://www.marshalls.co.uk/
[57] Source: Business in the Community, http://www.bitc.org.uk/resources/case_studies/marshalls_plc.html

- decreasing water consumption by 40% between 2003 and 2006. Additionally, the Brookfoot site is 95% self-sufficient in water, resulting in savings of £6,000 each month.

Other resource efficiency measures which are employed include the re-use of sustainable timber and recycled polyester pallets up to 20 times and the use of recycled aggregate in products such as Marshalls' Conservation Paving.

C6. Assessment of the Measures

Overall it can be seen that a range of resource efficiency measures are being implemented by the construction sector, with many of these are resulting in considerable cost savings. However, it is different to determine the total savings from one particular measure over a time period (for example, savings per year) since many of the savings are reported on a project by project basis. This means that they are not strictly comparable since each project is likely to be of a different value, particularly where smaller firms are being compared with larger companies. In addition, many of the examples given above suggest that resource efficiency measures may need to be undertaken in tandem or as a group since implementing measures singly may not be as effective or even feasible. For example, if waste is being segregated for recycling, it may be worthwhile considering whether any materials can be re-used on site, thus decreasing input costs as well as saving transport miles.

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Annex D: Food and Drink Case Studies

D1.1 Overview

The main aim of this study is to identify a method by which the effect of resource efficiency measures implemented by businesses on employment and competition can be determined.

This case study report relates to the second aim of the study, which concerns the testing of the method. Two sectors have been chosen for further analysis on the basis of the following criteria:

- type of environmental impact;
- potential for resource efficiency gains;
- relevance to Defra's policy remit;
- relevance of the sector to the UK economy;
- characteristics of the industry and market; and
- sensitivity to capital investment or capital redistribution

The sector analysis will focus on assessing resource efficiency measures applied by specific companies within the selected sectors as well as their impacts on costs, employment and competitiveness. A comparative analysis of the enterprise data will be used to assess firm-level sources of competitiveness, economic growth for the short and medium term in relation to resource efficiency measures and the consequences of the growth process for the employees.

The analysis aims to:

- identify resource efficiency measures characteristic of the sector;
- estimate the economic benefits of the applied mechanisms;
- estimate the impact on competitiveness of the applied measures;
- undertake a comparative analysis to determine what outcome the applied measures have resulted in with regard to competitiveness within the sector; and
- estimate possible long term costs and benefits of the applied measures.

D1.2 The Food, Drink and Tobacco sector in the United Kingdom

D1.2.1 Overview

There are over seven thousand food and drink manufacturing companies in the United Kingdom making it the largest manufacturing sector in the country. The sector is employing over four hundred-thousand people directly and is responsible for an additional 1.2 million jobs overall[58]. Companies within the industry are mostly small to medium size enterprises employing on average between 100-250 people, generating £72.8bn of turnover and a value added of £21.5bn.

[58] Food and Drink Federation (2009): **UK Food and Drink Performance**, statistics research report prepared by the University of Reading, available at www.fdf.org.uk

The sector leaves a substantial imprint on the UK economy by accounting for 15% of the country's total manufacturing output and it is the fourth largest food and drink manufacturing industry within Europe. GVA was valued at £22.8bn in 2008 (increase of 36% since 1995), contributing 14% of total manufacturing GVA.

Following continuous growth in profits over a ten year period, industry results regarding return on Capital Employed (ROCE) averaged 29.7% for branded food manufacturers and 17.6% for own-label companies in 2006.

The food industry alone accounts for:

- about 14% of energy consumption by UK businesses and 7 million tonnes of carbon emissions per year;
- about 10% of all industrial use of the public water supply;
- about 10% of the industrial and commercial waste stream;
- 25% of all HGV vehicle kilometres in the UK; and
- 12.5% of the UK workforce.

Table D1: Summary of Main Statistics for the Food, Beverages and Tobacco Sector, 2008

Sector	**Total Turnover (£ million)**	**Number of Enterprises**	**Approximate Gross Value Added (GVA) at basic prices (£ million)**	**Total Employment (average during the year) (thousand)**	**Total Stocks and Work in Progress – increase during the year (£ million)**
Manufacture of food products	66561	6500	18701	378	404
Manufacture of beverages	-	952	-	46	500
Manufacture of tobacco products	-	12	-	5	47
Food and beverage service activities	50032	120781	22121	1578	-19
Retail sale of food, beverages and tobacco, in specialised stores	12080	28491	3241	173	35
Agents involved in the sale of food, beverages and tobacco	4028	1298	620	7	137

Notes: Data for 2008 has been collected under SIC (2007). Please see Office for National Statistics (http://www.statistics.gov.uk/abi/) for further information.

Worldwide, the tobacco industry produces more than 5,400 billion cigarettes every year. Excluding China, which is currently the largest tobacco market, four international companies dominate the sale and manufacture of tobacco: Phillip Morris International, British American Tobacco, Japan Tobacco and Imperial Tobacco.

There are three major tobacco companies operating in the U:, Gallaher (which since 2007 has been a subsidiary of Japan Tobacco and thus the world's third largest tobacco manufacturer) and Imperial Tobacco, whose market dominance in the UK is close to 80%, and the world's second largest cigarette manufacturer, British American Tobacco. Within the United Kingdom the industry is employing close to five-thousand people directly and is responsible for another 80,000 jobs in suppliers, wholesale, distribution and retailing. The sector has published net revenues in excess of £10 billion for the years 2008/09[59].

Innovation

The sector is intensely competitive and production processes within the industry rely on technological advancements. Competitiveness is influenced by a number of factors, such as:

- price and availability of raw materials;
- regulations;
- public perception;
- economic environment; and
- environmental and animal welfare concepts.

In order to remain competitive, businesses must continually innovate. As the Food and Drink manufacturing industry is highly technology sensitive, innovation impacts the whole production cycle in view of the fact that it contributes to a reduction in the costs of manufacturing, storage and logistics as well as to the development of new techniques and products.

Even though the industry is characterised as highly innovative by spending on average £350m per year on research and development and launching 8,000 new products every year, these numbers are not clearly reflected in productivity. In international comparisons, productivity numbers are 30% less than that of the US and R&D intensity is only half of Japan's level. In comparison with other sectors in UK, labour productivity in food and drink manufacturing is 7% higher than for manufacturing as a whole and almost 30% higher than for the economy as a whole[60].

Innovation can be one of the ways businesses achieve their regulatory targets. For example, effective waste management/waste minimization practices contribute to the sustainability of operations by reducing waste at source, achieving cost savings and potentially creating new employment opportunities. Waste efficiency can best be achieved if it is applied as an integrated approach involving all stages of the production.

Legislative incentives encouraging companies to limit emissions can contribute to improvements in production mechanisms that allow a reduction in water/energy usage and effluent discharge volumes without compromising food hygiene. The key regulatory drivers towards resource efficiency are set out in Table 3 below. Regulations may also trigger environmental innovations that might contribute to offsetting the burdens and costs induced by regulations and create new markets for environmentally desirable products and processes.

[59] Tobacco Manufacturer's Association http://www.the-tma.org.uk/tobacco-smuggling.aspx

[60] Food and Drink Federation (2009): UK Food and Drink Performance, statistics research report

Cost Savings

Resource efficiency measures can lead to the reduction of direct and indirect costs and savings can be reinvested to accelerate production or sales. In order to identify the way cost savings arising from resource efficiency measures are used at company level, , it is important to identify savings arising from different measures and policies. Whether companies retain their savings as profit or use it to invest in their production or marketing processes depends on market specifics as well as the company's market position.

At company level, and even more so at a macro economic, level it is difficult to separate the actual cost savings that occur as a result of low-cost/no-cost quick-win resource efficiency measures as these savings are often part of an integrated approach to reformulate production mechanisms and processes and they add to already existing benefits.

During consultation carried out for this study, it has become clear that within the sector, businesses are often likely to use their resource efficiency savings to re-invest in their companies operation. Recycling savings and reinvesting in their companies operation helps to maintain or improve competitiveness. Moreover, businesses are keen to extend their practices and retain their consumer base by assuring that the whole supply chain adopts similar measures.

The implementation of resource efficiency measures can impact the perception of a company as well. Along with other factors such as Corporate Social Responsibility, business-to-business relations, supply chain mechanisms etc. it helps companies in displaying a "greener" image and thus strengthening their reputation.

Rebound Effect

As businesses take measures to implement a more efficient production process, potential savings are estimated using basic physical and economic indicators. In certain cases however behavioural responses might not fall in line with economic expectations. Depending on the market conditions and changing consumer demands, companies might be encouraged to use their savings from energy efficient production on increasing production capacity while exploiting the same resources.

The rebound effect is the difference between the projected and actual savings due to increased efficiency. It consists of direct, indirect and macroeconomic effects that might take place following the use of a more efficient technology/equipment. Under specific market conditions the rebound effect could actually turn an increase in efficiency into an increase in demand.

Legislatives incentives targeting efficient technologies as well as labour and energy cost reduction might have a larger rebound effect as businesses find themselves with a considerable amount of human and capital resource that might be transferred into production of other goods with adverse economic or environmental impacts.

Even though rebound effects vary greatly between sectors and technologies, long lasting impacts on the economy and the environmental are rare. The extent of a rebound effect depends on many factors and one of those is price sensitivity- where businesses or consumers are more prone to purchasing products at lower prices, high income groups are less price-sensitive. Nonetheless there are other factors influencing the extent of the rebound effect such as the availability of the specific resource, substitute materials and the maturity of the market as well that of the economy.

Employment

With an integrated process which is heavily reliant upon human resources, skills are one of the biggest challenges for the food and drink sector. Major skills shortages are reported in:

- management/ supervisory roles;
- technical operators – technologists, engineers, electricians;
- craft skills; and
- food scientists.

According to the UK Commission for Employment and Skills Working Futures 2007-2017 evidence report, the machine operatives category is the most important occupational group accounting for 1 in 4 of all jobs. Whereas demand for skilled trades and elementary occupations have fallen sharply (and according to projections it will continue to do so in the coming decades), other categories such as managers, associate professionals and sales and customer service occupations have seen increases with regard to their shares of total employment.

Other areas where job losses are forecasted due to a shift in demand are administrative, clerical & secretarial sales & customer service occupations. Increases are expected for managers and to a much smaller degree for professionals and associate professionals.

Employment is concentrated in three regions of England; North West (14%), Yorkshire & Humberside (13%); and the East Midlands (13%). The bakery (25%), meat (21%), other food (12%) and beverage (10%) sectors account for two thirds of the total jobs in the industry.

The following table on trends in output, productivity and employment illustrates the relation between the productivity of the sector and the employment rates.

Table D2: Trends in output, productivity and employment

Indicator	**1997-2002**	**2002-2007**	**2007-2012**	**2012-2017**
Output (% pa)	0.2	0.6	0.9	0.9
Employment (% pa)	-1.4	-2.1	-0.5	-0.8
(000s)	-34	-48	-11	-17
Productivity (% pa)	1.6	2.7	1.4	1.7

Source: UK Commission on Employment and Skills, Evidence report (2008) Working Futures 2007-2017

Employment within the sector is dependent upon the overall economic performance as well as implementation of technological improvements and changing consumer demands. Other drivers such as regulations and globalisation also have an impact on employment.

Consultations have shown that employment is unlikely to increase due to implemented low-cost/no-cost quick-win resource efficiency measures. Companies are more likely to invest in external consultants in order to implement these types of resource efficiency measures than to add to their workforce. Even though the demand for additional jobs remains largely unaffected certain skills are likely to be added to existing tasks presenting new embedded knowledge within the sector.

The applied resource efficiency measures impact not only the internal mechanism of the businesses but effectively their supply chain as well. As companies demand their supply chain to implement similar measures, training of employees and raising their awareness is crucial in maintaining practices. An indirect effect of the applied measures is through costs savings and growth of business which might lead to a rise in employment. Even if some of the introduced efficiency measures do not directly impact employment, in the short-term they can contribute to additional skill requirements, support jobs connected to manufacturing and have an influence on competitiveness by highlighting cost reduction schemes.

Energy efficiency measures, which might have an impact on the whole supply chain, seek to economise the amount of raw material and energy inputs used and thus generate cost savings. Depending on the long term growth strategy of the particular business, jobs can be retained or even increased.

According to current forecasts employment levels for the sector will continue their downward spiral. Nonetheless, since problems with recruiting and retaining employees persist within the sector, it is expected that the demand to recruit will continue.

D1.3 Key Policy Drivers

There are several DEFRA led initiatives relevant to UK business achievements in resource efficiency. Those relevant to the Food, Drink and Tobacco sector are summarized in the table below.

Moving towards and maintaining sustainable production is not only a regulatory incentive; food and drink manufacturers are also responding to consumer demands and thus delivering significant business values as well by reducing excess materials and cutting back on emissions.

The impact of regulatory incentives is nonetheless substantial as they define applicable technologies and best practice measures. Regulatory compliance costs on the other hand can prove to be a significant burden for a sector that is comprised mostly of small and medium sized enterprises and regulatory policies are required to align government and industry interests and therefore take into consideration the long-term characteristics related to market trends as well as industry practices when determining priorities.

Table D3: Summary of Legislation by Origin

Legislation	Description / Relevance	Wider industry impact	Impact on production and employment
IPPC	Establishes emission limits per site, for industrial emitters of air pollution, an incentive for increased resource efficiency	Emissions controls / effluent treatment (including invest in new equipment to reduce exposures) Reduced production / withdrawal from market Process restrictions Change in Processing Methods.	To meet the legislative criteria of emission limits companies might have to cut back on production or invest in new equipment/production processes which might negatively effect profitability and employment on the short term. At the same time these investments made to meet standards reduce production costs in medium to long term and might have a positive impact on profitability, growth and employment.
European Union Emission Trading Scheme	Allocation and trading of greenhouse gas emission allowances. WRAP estimates that around 18 per cent of total UK greenhouse gas emissions are related to food production and consumption.		
Renewable Energy Directive	Legally binding carbon emissions reduction targets and setting of national carbon budgets. Encourages development of lower energy-intensity processes across range of sectors.		
Water Framework Directive	Establishes targets for water quality in river basins. Greater water efficiency may reduce treatment costs for industrial users and water companies	Setting Concentration Limits Emissions controls / effluent treatment (including invest in new equipment to reduce exposures)	
Packaging and packaging waste	Contains provisions on the prevention of packing waste, on the re-use of packaging and on the recovery and recycling of packaging waste	Waste management: including waste management systems adapted to collection, recovery. Cost-benefit ratio of recycling depends on the material and application used.	A change in waste management practices and waste minimization might potentially impact the whole supply chain and contribute to a reduction of production costs in the medium to long term. Changing the production line with the possible withdrawal or change in products and the implementation of new processes might increase costs on the short term. Employment figures overall might remain unchanged on a company level but different quality and skill requirements might lead to a reallocation of workers in different units of the production process.
Landfill Directive	Target 35% reduction in landfill waste from 1995 levels by 2016 established, affecting the landfill tax paid by commercial waste producers	Waste management Change in Processing Methods	A change in waste management practices (increase authority recycling, and cut industrial/commercial waste going to landfill) and waste minimization might potentially impact the whole supply chain and contribute to a reduction of production costs on the medium to long term.

The impact of the above regulations for the food and drink industry is manifold. As incentives, they encourage businesses to move towards sustainability by identifying and reducing processes where there is an excess use of resources. At the same time standards measuring progress are crucial for which performance indicators of the specific subsectors within the industry can be established.

It is essential that the regulatory framework governing the industry finds an appropriate balance between encouraging cost-effective growth and ensuring environmental protection. It is in the interest of both the industry and the regulatory bodies to identify the procedures relevant for the sector that are most in need of additional incentives as well as to simplify the processes and clarify the requirements within the policies without a risk to environmental effectiveness or heath and safety.

UK Initiatives

Alongside regulatory measures introduced by the European Union, there are a range of UK government backed national initiatives such as the Federation of House Commitment, an initiative developed by the Food and Drink Federation and Envirowise and launched in 2008 that provides companies with a systematic approach for improving water efficiency. The initiative is aiming to help companies to reach a 20% reduction in their water use against a 2007 baseline by 2020.

Other government incentives such as the Enhanced Capital Allowance (ECA) scheme can contribute to the implementation of long-term energy efficiency measures implemented by businesses by enabling them to write off 100% of the cost of energy saving investments, such as plant or machinery specified on the Energy Technology List, against taxable profits in the year of purchase.

The ECA water scheme is managed by the Department for Environment, Food and Rural Affairs (Defra) and HM Revenue and Customs in partnership with Envirowise. The ECA water scheme includes a variety of technologies, such as water efficient taps, toilets, monitoring equipment and industrial cleaning equipment.

The Climate Change Levy is a tax on electricity (excluding renewable electricity), gas and fuel oil use by business; it aims to encourage energy efficiency and reduced greenhouse gas emissions. The Climate Change Agreements give organisations who deliver reductions in energy use an 80% discount from the Climate Change Levy in certain energy sensitive sectors.

The Carbon Trust is an initiative of the UK government aimed to help businesses to achieve the targets set by the 2008 Climate Change Act. It supports low carbon technologies and advises businesses on a wide range of innovative solutions on cutting emissions, including technical expertise and venture capital investment for low-carbon businesses.

D1.4 Resource Efficiency Measures

As noted in our scoping report (RPA and Cambridge Econometrics, 2010), resources consumed or produced by economic activity include water, energy, materials (products and raw materials) and discarded resources such as waste. As each resource is scarce, increased efficiency can contribute to sustainable production and consumption as well as to the competitiveness of the industry in question, provided these resource savings result in lower production costs and/or more innovative products and processes.

The food and drink industry is highly resource driven – using water, electricity and generating waste throughout most of its production processes. Based on the main resources used during production processes the reduction targets include:

- Waste;
- Water;
- Energy consumption; and
- CO_2 reduction.

Quick-win/low cost resource efficiency measures identified during the course of this study are set out below in Table D4.

Table D4: Short-term resource efficiency measures		
Category	**Measure**	**Supply or Demand Side**
Waste	Identifying production processes generating waste	Supply
Waste	Assessing types and reasons of losses	Supply
Waste	Setting targets for improvement waste efficiency	Supply
Waste	Lowering waste input	Supply
Waste	Re-use of packaging	Demand
Waste	Ensuring sufficient time for process lines to be cleared and outgoing brand to be packed rather than being sent to waste before brand changes	Demand
Waste	Standardizing packaging specifications of retailers	Supply
Waste	Reducing excess materials in packaging	Supply
Energy	Switching off lights	Demand
Energy	Installing insulation	Demand
Energy	Installing daylight sensitive lighting	Supply
Energy	Better control of ventilation extract	Supply
Energy	Heating system insulation and reflective panels behind radiators	Supply
Energy	Electronic storage of documentation	Demand
Water	Select valve and piping material to minimize corrosion and leaks	Supply
Water	Provide suitable work areas, handling tools, and training to operators so they can avoid creating spills	Supply
Water	Plug floor drains in material storage areas	Supply
Water	Where possible use dry cleanup methods; provide brooms, vacuums, and absorbent	Supply
Water	place meters on water supplies feeding process equipment	Supply
Water	Reuse wastewater from processes in other processes that do not require high quality water	Supply
Water	Use counter current or multi-stage rinsing to reduce water use	Supply
Water	Remove water supplies from storage areas	Supply

The measures listed in Table D4 above are categorized as no cost/low cost measures as their impacts on resource efficiency can be implemented with relatively low investments and their impacts on production costs, employment and profitability/competitiveness can be measured in the short term.

Supply side measures focus on the internal processes of manufacturing but it is equally important to address demand-side issues that impact consumer behaviour. To extend the impact of resource efficiency measures applied by businesses it is crucial to assess how consumers react to the technological innovations. Technology can contribute to reducing levels of consumption through extending product lifetimes or through more durable and/or serviceable products. At the same time technological innovations may be subject to rebound and displacement effects whereby consumers absorb savings and replace them with other activities that may be even more harmful to the environment.

The following sections provide greater detail on the resource efficiency measures actually implemented by companies. Through a set of case studies the economic and social impacts of the implemented measures are indicated. The Food and Drink sector is characterised by strong competition where perception of businesses can lead to an increase in profit therefore companies are eager to invest in measures that might reflect an environmentally conscious image and at the same time save costs. Within the Food and Drink Sector the most often implemented resource efficiency measures relate to waste, water and energy saving.

D2 Selected Resource Efficiency Measure 1: Waste Management

D2.1 Waste Management

The food, drink and tobacco manufacturing industry produces close to 7.2 million tonnes of waste per year, the majority of which is being reprocessed and approximately 1.9 million tonnes of it is sent to landfill[61]. The environmental concern associated with solid waste coming from food processing plants is that it is high in nitrogen, phosphorus and carbonaceous material which in a landfill decomposes slowly, and often anaerobically, due to a deficit of oxygen. This in turn produces methane gas and acidic leachate, both of which can have a significant environmental impact. As the waste sent to landfill is often unsuitable for animal feeding due to the addition of coagulants in food-processing, the remaining option would be to compost and add to soil at appropriate rates. Therefore policies encouraging waste management practices to divert from using landfill sites to reducing input or towards recycling play a very important role in the sector.
Waste generated through food production is typically broken down into two categories: direct and indirect waste. Direct wastes are stored or processed raw materials that can either be intentional or unintentional. Intentional wastes can include wastes such as peelings from vegetable processing, bones from meat processing etc; unintentional wastes are resulting from poor inventory control or improper maintenance. Indirect waste is the lost portion of direct waste resulting in sludge.

Packaging used during production contributes greatly to industry waste arising. Whereas food safety and hygiene criteria measures put a limit on the amount of packaging necessary, reduction of excess materials is nonetheless an important element as its implementation can contribute to a significant reduction in waste as well as financial savings related to waste segregation and recycling. Reductions in packaging impact the whole supply chain as varying specifications of retailers regarding food packaging can be an obstacle to recycling. Therefore, standardisation in packaging as well as segregation of packaging waste from the general waste stream can significantly help cutting excess amounts of material input.

In order to implement effective measures to combat erroneous waste management practices, identifying the source of waste arising in the production process (e.g. packaging or manufacturing) as well as the type of waste is crucial. Measuring the amount of waste that is being generated through the production process is also an important tool in providing

[61] DEFRA Waste strategy for England 2007

baseline data for tracking progress, whereas continuous monitoring of the source of waste arising helps in identifying raw material wastage. As the table below shows, food manufacturing alone produces over five million tonnes a waste per year in the United Kingdom.

Table 5: Estimated total waste arisings (by type) from the UK food and drink supply chain (by stage) and household, per year (tonnes)[62]

Supply chain stage	Food	Packaging	Other	Total
Manufacturing	2,591,000	406,000	2,019,000	5,016,000
Distributional	4,000	85,000	9,000	98,000
Retail	362,000	1,046,000	56,000	1,464,000
Household	8,300,000	3,600,000	20,566,000	32,466,000
Total	11,257,000	5,137,000	22,650,000	39,044,000

Source: FDF, Environment Agency, WRAP/DHL, WRAP, Eurostat

Waste management practices within the industry have the primary goal to minimize the amount of waste that is being generated; this goal can be achieved either by limiting the amount of waste that is being produced or by focusing on reducing the waste output by waste reproduction or recycling. Resource efficiency measures applied to waste management can include the application of clean technologies which impact the whole production process and can, on the one hand enhance the safety and quality of the products, and at the same time make a significant contribution to the reduction of the energy requirements as well as to that of the environmental impact.

Costs and Prices

The processing of waste has a list of associated costs such as raw materials, water, energy and labour. Therefore, regularly monitoring the amount of waste that is being produced can help in identifying peak waste producing processes and times and thus focus reducing measures to specific activities.

As the individual case studies show, improved efficiency regarding waste management practices can contribute to a reduction of costs.

The true cost of waste makes up an **average 4% of a typical business' turnover[63]**. Most companies can achieve savings of at least 1% of turnover by implementing a systematic waste minimisation programme[64].

D2.2 Example 1: Jordans & Ryvita Company[65]

The Jordans & Ryvita Company is the result of a recent merger; it now employs close to 400 people and its sales for 2008 reached $138 million. The company has recently transformed its approach to waste management and, as a result, reduced the amount of waste from its Stockport manufacturing site sent to landfill by 96%. It has modified its waste operations by employing just one waste contractor instead of the previous practice of employing seven different waste contractors and has focused on recycling packaged food products into constituent parts, namely food, cardboard and plastic.

[62] WRAP Waste arisings in the supply of food and drink to UK households 2010

[63] Technology Strategy Board: Resource Efficiency Strategy 2009-2012, available for download at http://www.innovateuk.org/

[64] Reducing water and waste costs in fruit and vegetable processing 2001 Ashact Ltd

[65] Food and Drink Federation

The food element is removed from packaging by a series of mechanical processes and typically ends up in animal feed. Packaging is separated in-house and recovered using "jet shredder" waste technologies which separate film, carton and foodstuffs, all of which can then be recycled separately.

All plastics are recovered for recycling as well as metals and hazardous waste. New equipment was also installed, including waste compactors and waste segregation bins. As a result, waste sent to landfill has been reduced by 96%. As well as being good for the environment, this work has created clear business benefits for Ryvita. The costs associated with disposing of waste have reduced by 50% since late 2007.

D2.3 Example 2: R Mathieson & Sons Ltd[66]

Established in 1872, the bakery of R Mathieson & Sons Ltd employs over 400 people and has an annual turnover of £6.5million. Their structured programme for reducing waste and improving environmental performance resulted in benefits such as: cost savings of £56,700/year and further savings of £14,300/year, reduction of waste to landfill of 31tonnes/year and a 2% reduction in the ratio of energy to volume of production.
Since 2001, the company has responded to pressures from increased waste costs by implementing a structured programme of progressive waste minimisation. As a result, significant savings have been achieved from minimising costs associated with waste, effluent, fuel and energy. The key to this success has been the active involvement of employee teams who have helped to identify areas requiring waste minimisation. Increased awareness across the company, along with the drive and enthusiasm of an appointed waste champion, has stimulated ideas for several initiatives. The waste minimisation initiatives have brought significant benefits for Mathiesons, including:

- reduced raw material consumption and, through a recycling programme, lower waste disposal costs;
- a reduction in energy and water consumption and effluent disposal costs;
- increased staff awareness and involvement.

Through a number of low-cost and no-cost initiatives, Mathiesons has achieved the following savings:

- Waste disposal costs have fallen by £12,000/year (66%)
- Savings from minimising wastage of bakery products and frying oil of £3,700/year.
- Efficient scheduling of deliveries led to savings of £28,000/year from the reduction in fuel consumption and in the number of vehicles used.
- Savings in labour costs of £13,000/year.

The environmental benefits associated with Mathiesons' initiatives to minimise waste include:

- a reduction of 31 tonnes/year (21.2%) of waste to landfill;
- decreased consumption of raw materials, water and energy;
- reduced fuel use and pollution from transportation (delivery miles reduced by 30%).

D2.4 Example 3: Burts Potato Chips Company[67]

An audit at snack foods manufacturer Burts Potato Chips pinpointed a number of opportunities to reduce production costs and achieve environmental benefits. As well as

[66] Envirowise: Bakery reduces waste and sees profits rise

[67] Envirowise Snack foods manufacturer improves efficiency by reducing waste

driving immediate cost savings, the audit highlighted areas where waste minimisation could be built into the company's plan to relocate to a new and larger site. Potatoes and parsnips are sourced from local growers and are delivered to the factory in 2-tonne loads. Approximately 24 tonnes of potatoes and parsnips are currently processed each week.

Following the environmental audit, a trial was carried out to weigh the amount of frying rejects produced on each process line. These data were used as a key performance indicator to assess process efficiency and to track areas where improvements could be made. During the trial, rejected crisps were passed through an optical sorter that assesses colour and moisture content. The trial revealed that:

- around 500 kg/week of frying reject waste was being generated; and
- manual sorting was removing large quantities (up to 90%) of crisps that were suitable for sale, i.e. 450 kg/week.

This finding prompted the company to specify an optical sorting process for the new site. The optical sorter comes with a cost of around £100,000, but is expected to result in cost savings of over £175,000/year at current production rates through reduced wastage and increased production efficiency. This represents a payback period of seven months. Even greater savings are anticipated when production expands at the new site.

Table D6: Summary of costs and savings

Waste minimisation measure	Saving (£/year)	Cost (£)	Payback period
New seasoning system (implemented)	25,000	100,000	4 years
Optical sorting system (planned)	cc 175,000	100,000	7 months
Use of production waste as animal feed (planned)	cc 10,000	-	immediate
Source: Envirowise case study: Snack foods manufacturer improves efficiency by reducing waste (2006)			

Operations at the existing site generate waste associated with factors such as ageing equipment and the lack of guards on conveyors. The latter results in potatoes and crisps falling to the floor and becoming waste. The company expects to reduce waste of this type at the new factory through careful design of the plant layout and sourcing of appropriate equipment.

Redesign of the transit packaging for a key account customer has increased the packing density of boxes on a pallet by 147%, allowing a higher weight to be carried per pallet. This has reduced handling, fuel and time costs. In addition, use of thinner cardboard in the boxes has reduced the weight of packaging waste generated by the end-user.

D2.5 Example 4: Premier Foods[68]

The company has committed itself to sending zero waste to landfill by 2015 and implemented an integrated waste management practice by setting up a group waste management steering committee, with the objective of developing an aligned approach to reduce dependence on landfill, and ultimately to send zero waste to landfill. It is being achieved by improving communications, sharing best practices, and facilitating engagement across each of its divisional businesses.

[68] Food and drink Federation http://www.fdf.org.uk/casestudies/waste-premier.aspx

In 2008, Premier Foods' total waste disposal to landfill was reduced from 38,000 tonnes to 30,000 tonnes, representing a 21%, year on year reduction of waste sent to landfill. Up to November 2009, it had diverted a further 31%, or 9,300 tonnes, from landfill against a target to reduce waste to landfill by 20% in 2009.

Improvements have been achieved through close partnerships with suppliers, resulting in a combination of site-based waste reduction initiatives and improved waste segregation at source, which has led to an increase in the number and variety of materials sent for recycling and recovery.

In 2010, the company have set a target to divert a further 20% of the waste produced from landfill, equating to an additional 4,140 metric tonnes.

D3 Selected Resource Efficiency Measure 2: Water efficiency

D3.1 Water Efficiency

The food processing industry uses water for the majority of its activities therefore it is one of the largest users of process water in the UK[69]. According to the Food Industry Sustainability Strategy (FISS), the food industry in England and Wales is estimated to use 430 mega litres per day from the public water supply. It is also estimated to make direct abstractions of 260 mega litres of water per day. Water consumption, similar to electricity, is another resource input that requires improved technologies and practices to reduce the amount used or to create additional water supply sources.

Table D7: Total water used by the food and drinks industry[70]

	Total water used (excluding that embedded in products) (m3/tonne product)	Total water used (excluding that embedded in products) (m3)
2007	2.09	28,029,150
2008	2.06	27,553,059
Source: Federation of House Commitment: Reducing water use within the Food and Drink Industry Progress Report: 2009, Envirowise		

In the industry, water plays a significant role in transporting, cleaning, processing and formulating products, as well as in meeting many federal sanitary standards. Facilities implementing water conservation programs sometimes struggle to balance these needs with the many benefits of reducing water usage. Savings can be made in activities such as:

- product washing
- cooling
- cooking
- Blanching
- thawing
- Packing and filling lines
- conveying systems
- Vessel and pipe cleaning
- plant and equipment cleaning
- crates, bottle and container washing
- filters
- Workstations

[69] Envirowise guide: water minimization in the food and drink industry

[70] FHC progress report 2009

- utilities
- Management and maintenance
- Recycling

<u>Costs and Prices</u>

The food and drink manufacturing industry is made up of a wide range of subsectors that use water in different ways. A business processing poultry can typically use around 27% of the total water use for carcass chilling, whilst cleaning in place might account for around 25% of total water usage during the processing of skimmed milk.

By consuming varying amounts of water businesses belonging to specific subsectors within the industry face different amounts of costs as both the purchase of water as a resource and the discharge of it constitutes to remain a significant part of companies' operating cost.

Water saving initiatives range from low cost and easy to implement solutions through to those that require capital investment and longer lead in times. As such, some of the actions being taken forward will not necessarily see immediate savings.

D3.2 Example 1: Hazeldene Company

Hazeldene which is part of the William Jackson Food Group, has managed to save in excess of 20% of its water usage at its Wigan plant that equals to approximately 70,000 m3 per year.

As well as re-introducing an employee awareness and 'turn off' campaign – which have previously been used to good effect – the company has invested £15,000 to improve the efficiency of its production lines.

All the divisions of William Jackson Food Group have increased both their frequency of water monitoring and, in some cases, the accuracy through sub-metering. This has been enabled by the purchase of transportable flow meters, which can be shared by divisions and also by installing fixed meters where justified. Water best practice techniques are also shared between divisions.

D3.3 Example 2: Burton's Foods Company

As the company is taking part in the Federation House Commitment (FHC) since 2008 it conducted a full scale water investigation across all sites, relative to the tonnes of product baked. This detailed analysis indicated anomalies at its Moreton baking site on the Wirral and further analysis has been carried out via detailed sub-metering and this has identified the areas where water efficiency savings could be made.

A site-specific action plan was put into place and, by the end of 2009; the company expects to have saved more than 73,000 m^3 of water at this site alone – equivalent to a 42% reduction in water used per tonne of product baked.

D3.4 Example 3: Dairy Crest Company

Having joined the FHC, Dairy Crest undertook a benchmarking exercise across its sites. This identified that the Hanworth site's water use per tonne of milk processed was higher than that at a similar site in the group.

To investigate, an exercise was carried out on key items of equipment at the site, which showed that the bottle washers were using significantly more water than their designed usage.

The jet bars on both bottle washers had jet nozzle damage and wear, increasing the orifice sizes, resulting in the bottle washers using a considerably higher amount of water, with the machines running out of balance.

It was proposed that all 64 jet bars and 1,250 jets be changed for new stainless steel versions on both bottle washers. The project costs to achieve this were £57,000.

When the jet bars were replaced, a 5,502 m3 per month water reduction was realised, equating to 66,024 m3 per year water and effluent savings. A reduction in steam use of 166 tonnes per week was also achieved, with the total savings estimated at £200,000 per year.

Since 2007, Dairy Crest have seen relative water savings of 8% across the business and a 16% reduction in m3 of water used per tonne of milk processed at their Hanworth site.

D3.5 Example 4: Yeo Valley

Yeo Valley Organic is part of a family-owned farming and dairy business producing organic yogurts, funded in 1974 and based in Somerset. The company has completed a thorough assessment of its operation cutting excess materials in relation to its packaging procedures as well as re-examining waste management practices.

Packaging is one of the company's main waste streams. Any large, undamaged cardboard boxes are sent for re-use, while small or damaged boxes are compacted and sent for recycling. Plastic waste is also compacted and sent for recycling. From one dairy alone, 477 tonnes of waste were diverted from landfill in 2007, saving over £36,000.

Using shelf-ready packaging trays made from recycled PET (RPET) allow 38% more product to be placed on pallets. Annually, this saves about 570 lorry trips between the dairies and the cold store, saving about 22,800 road miles worth £37,620. Furthermore to minimise the wastage of valuable raw materials, Yeo Valley uses 'smart planning' to produce only what is required. As a result, the net loss from input to output is below 7%.

The company's staff has taken part in a program raising awareness about water efficiency and has implemented a range of water saving measures, including:

- During the wash-down process the staff is encouraged to collect water from the machines and to control run-off using squeegee mops instead of continuous hosing.
- The diameter of hoses has been decreased to reduce the water output.
- The dairy requires hand washing throughout the majority of the site. Infrared sensors have been fitted to turn the taps on and off automatically, and to limit the amount of water used.

These initiatives saved 7,500 m3 of water in 2007. The company has installed a water recycling system in the homogeniser units to capture and re-use about 2m3 of water per hour. The system is expected to save 15,000 m3 per year.

D4 Energy consumption

D4.1 Energy Efficiency

As the industry is a substantial user of energy (with basic processes such as cooking, heating, drying) exploring the potential for cost cutting measures and renewable heat technology is significant. Energy prices make up a substantial part of direct costs – therefore one of the applicable baseline low-cost/no-cost measures include raising awareness among the employees and assuring production mechanisms do not excessively use energy resources.

A well constructed energy management system might prove critical for the successful operation of a business. Not only would it reduce costs of operation in the short term but it contributes to a better understanding on the energy requirements and available alternative resources of the particular processes.

The food industry uses energy for food processing, preservation, safe and convenient packaging as well as storage. Also a great deal of energy is consumed through heating buildings, refrigeration and the transportation of raw materials and products.

Even though technological developments of recent years (introduction of heat-transfer systems and hybrid heating processes) have contributed to reductions in the amount of electricity used, thermal processing and dehydration remain one of the most commonly used methods for food preservation and require a significant amount of energy. Process heating uses approximately 29% of total energy in the food industry, while process cooling and refrigeration demands about 16% of total energy inputs. An increased share of renewable energy sources could slowly reduce the amount of conventional fossil fuel utilization.

Costs and Prices

As energy costs are strongly embedded into overall production costs any reduction in energy use has an immediate effect on the total cost. The cost-effectiveness of the applied measure depends heavily on the input costs - the quick-win options – such as raising awareness among the employees or a turn-off lights campaign - generally require small scale or no investments their return in savings can be measured on the short term. Other supplementary investments can also reinforce benefits. However, these might require an overall overview of the electricity system specifics. In order to assess the real benefits and to assure a more cost effective operation on the long term the initial investment costs must be countered by the lifetime costs.

Cost of energy efficient improvements may differ according to the extent of the improvement. In the event that the investment is part of a regular replacement/refurbishment cycle, only costs related to the improvement shall be taken into account, whereas in the case of retrofitting, the full cost of replacement is considered.

D4.2 Example 1: Beefeater Company

Part of the Whitbread Group, Beefeater with almost 200 outlets, is the biggest full service restaurant group in the UK. An average Beefeater restaurant has some 8,000 covers a month and a typical electricity bill in 2004/05 of c.£14,000.

During a refurbishment programme, improvements were made to raise energy conservation specifications as buildings housing the restaurants were found to be thermally inefficient.

Action taken:

- insulating all accessible roof spaces;
- draft proofing exit doors to cold rooms & cellars;
- installing daylight sensitive lighting;
- installing PIR (passive infra red) movement sensors (e.g. for lighting);
- better control of ventilation extract;
- installing timers on air conditioning and similar electrical systems to ensure they are only used when needed;
- use of digital room thermostats to control room temperatures efficiently;
- heating system insulation and reflective panels behind radiators; and
- ensuring that flush controls in toilets work properly.

Project Managers have also been required to complete a pro forma of details on all work carried out, within 4 weeks of completion, so that energy and CO2 reduction benefits can be tracked and quantified.

Achievements and Benefits:

- runding was 'ring fenced' at £1,800 per project;
- completing the work as part of a bigger refurbishment contributes to time and cost savings by eliminate disruption during normal trading periods; and
- when a refurbishment takes place, a new lighting layout and improvements to air conditioning form part of the change. Trade also grows significantly. As a result it is difficult to isolate precise energy savings, but draft exclusion, insulation and water or time controls reduce usage by established norms.

D4.3 Example 2: Whitbread Company

Whitbread plc is the UK's leading leisure business, managing hotels, restaurants, sports, health and fitness clubs. In 2001, Whitbread's annual energy bill was in excess of £40m and this was identified as a major target for efficiency savings.

There are over 4,500 utility billing points throughout Whitbread's 1,400 properties and a wide variety of control and management systems in place, many involving complex 24/7 site activity. Sites vary in scale from small Costa coffee operations to international scale venues.

Action taken includes the improvement of data accuracy, establishing model profiles and identifying areas of potential over-consumption. In the case of similar restaurants or hotels, for example, if the buildings are virtually the same, energy consumption can be estimated relative to turnover and climate. Exceptional profiles helped to focus further action to establish whether the levels of consumption indicated by monitoring data were accurate, including:

- energy bill validation and verification, including discussions with utility providers; and
- undertaking a meter installation project to bring sites up to a standard that would allow effective data collection and analysis.

The meter installation project included extending installation of half hour electricity meters to almost all sites (60% already had half hour meters) and installing independent metering of gas and water in large sites.

Data was then collected from all meters on a daily basis to build 'half hour' usage profiles, giving a full understanding of how energy is used throughout each day for each outlet metered. Using this data and working with suppliers, a new reporting system was developed which resulted in accurate billing data being available much more quickly. This allowed for automatic adjustment of incorrect charges – in effect ‘self billing’. Obtaining better data not only resulted in savings through more accurate bills, but also allowed for better housekeeping practices and more successful energy efficiency programmes based on actual rather than estimated data.

Achievements and benefits

For a cost of less than £500 per meter fitted per site (in addition to a small annual management charge per site for automated reporting), the benefits were:

- reduction in energy costs across the total group of over £3.0m in first year;
- over £1.2m claimed back through incorrect billing of energy and water;
- re-negotiation of group tariffs, ensuring on-going savings of £1.0m per year for energy;
- reduction in water costs of £0.4m over the year through reduced leakages and wastage;
- ‘Self billing’ of electricity;
- ability to set up annual budgets for sites based on accurate historical data rather than estimates and hence deliver on-going improvements; and
- ability to import data from the energy database directly into the accounting system and P&L reports.

This activity contributed to Whitbread’s 2.7% reduction of energy used that year, which represents a reduction of 10,600 tonnes in carbon dioxide emissions.

D4.4 Example 3: Tideford Organics

Tideford organics is a food manufacturer, with its main products being organic soups, sauces and puddings. The company has been operating since 1997; it has a staff of 15 and an annual turnover of £1 million.

The company has implemented thorough resource efficiency measures that included a monitoring and efficiency programme for electricity, LPG and water in accordance with the training of the staff to understand and implement the appropriate measures.

The project has resulted in overall annual savings of £7,000 including a saving of £5,000 a year with utility costs reduced by 15% through implementation of monitoring and efficiency programme and an additional saving of £2,000 a year with the implementation of new waste minimisation and recycling programme.

D5 Assessment of the Measures

Effective management of water and energy use in food processing is essential, not least for legislative compliance and cost reduction. Resource efficiency practices highlighted that one of the key points in building up measures is the identification of processes and their resource intake. Examples within the case studies suggest that low cost measures such as integrated waste management practices and focus on recycling can contribute to the greening of the operation by reducing landfill waste up to 96%. At the same time measures such as employee training or identification of processes where improvements could be made can also boost cost savings up to 65%. Water efficiency measures such as a turn-off campaign amongst employees have an immediate effect. Along with small scale investment such as the purchase of meters it can contribute to significant cost reductions.
Energy efficiency measures such as insulation, draft proofing of doors, emplacements of thermostats can contribute to energy savings as well as CO_2 reductions which can not only

directly cut costs for companies but through the Climate Change Levy, it can also mean tax reductions.

Each of our case studies raise a number of issues and the possibilities of achieving different impact through implementing resource efficiency measures. Impacts can be grouped around three main areas:

- business solutions (solving technical challenges such as production and efficiency);
- capacity (identifying improvements and adopting a higher value/knowledge-based approach); and
- strategy (improving financial status, market niche, enhancing reputation).

There are opportunities for improving energy efficiency in the food industry through evaluation and addition of effective governmental energy policies and voluntary process analysis and improvement. Future directions for energy efficiency studies should focus on improving existing plants, developing energy-efficient process technology, improving and expanding demand side management programs, creating informed and reasonable energy policies, and further research in the possibilities of zero-discharge plants.

Quick-win measures include:

- establishing key performance indicators;
- recycling, re-use schemes;
- electronic storage;
- water mass balance;
- training of employees;
- regular preventive maintenance;
- regular waste audits; and
- energy use monitoring of processes.

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Annex E: Consultations

Table E1: Consultation				
Contact	**Communication means**	**Topics covered**	**Response and Information/Documents received**	**Follow-up**
National agencies				
WRAP	Conference call	Types of resource efficiency measures implemented by companies within the selected sectors; relevant legislation; resource efficiency measures as CSD; rebound effects		
NISP	Conference call	Measures implemented by businesses and their impacts on employment and competitiveness, overall economic impact	NISP Pathway Program report	
Envirowise	e-mail			
Enviros and Aldersgate Group	Conference call	Cost savings and employment of businesses implementing resource efficiency measures, types of recommendations made		
ESAUK	e-mail	survey		
Green Alliance	e-mail	survey		
IEMA	e-mail	survey		
BITC	e-mail	survey		
Trade Associations				
Food and Drink Federation	e-mail	survey		
Dairy UK	e-mail	survey		
NHBC Foundation	e-mail			

Table E1: Consultation				
Contact	**Communication means**	**Topics covered**	**Response and Information/Documents received**	**Follow-up**
British Meat Processor's Association	e-mail	survey		
The Brewing, Food & Beverage Industry Suppliers Association	e-mail	survey		
Association Of Cereal Food Manufacturers	e-mail	survey		
Institute of Grocery Distribution	e-mail	survey		
CIRIA	e-mail	survey		
Construction Industry Council - CIC	e-mail	survey		
The Chartered Institute of Building	e-mail	survey		
Engineering Construction Industry Association (ECIA)	e-mail	survey		
CECA Civil Engineering Contractors Association	e-mail	survey		
The Construction Equipment Association	e-mail	survey		
Tobacco Manufacturers Association	e-mail	survey		
Federation of Small Businesses	e-mail	survey		
British Retail Consortium	e-mail	survey		
Regional Agencies				

Table E1: Consultation				
Contact	**Communication means**	**Topics covered**	**Response and Information/Documents received**	**Follow-up**
Yorkshire Forward	Conference call	Types of measures implemented by businesses and their impact on competitiveness in the region	Ex-post assessment of resource efficiency grants, contacts to other relevant organisations	
Resource Efficiency/Renewables East	Conference call	Cost savings and employment of businesses implementing resource efficiency measures, types of recommendations made	ERDF program report and baseline data	
South West Regional Development Agency	Conference call	Cost savings related to the implemented resource efficiency measures within the selected sectors	Ekosgen report, Envision data on case studies	
North West Development Agency	e-mail			
CO2 Sense Yorkshire	e-mail			
East-Midland Development Agency	e-mail			
London Development Agency	e-mail			
Private sector organisations				
TNEI	e-mail			
YFM Group	e-mail			
Proenviro consultancy	e-mail			
Vion Food	e-mail			
Marks&Spencer	e-mail			

Annex F: MDM Annex

F1 Introduction

MDM-E3, the Multisectoral Dynamic Model of the UK economy, is maintained and developed by CE as a framework for generating forecasts and alternative scenarios, analysing changes in economic structure and assessing energy-environment-economy (E3) issues and other policies. MDM-E3 provides a one-model approach in which the detailed industry and regional analysis is consistent with the macroeconomic analysis: in MDM-E3, the key indicators are modelled separately for each industry sector, and for each region, yielding the results for the UK as a whole. MDM-E3 is one of a family of models which share the same framework, general design, methodology and supporting software; the scope of the E3ME model is European; that of E3MG is global.

To analyse structure, the E3 models disaggregate industries, commodities, and household and government expenditures, as well as foreign trade and investment, and the models incorporate an input-output framework to identify the inter-relationships between industry sectors. The E3 models combine the features of an annual short and medium-term sectoral model estimated by formal econometric methods with the detail and structure of input-output models, providing analysis of the movement of the long-term outcomes for key E3 indicators in response to economic developments and policy changes. The models are essentially dynamic simulation models estimated by econometric methods.

MDM-E3 retains an essentially Keynesian logic for determining final expenditure, output and employment. The principal difference, compared with purely macroeconomic models, is the level of disaggregation and the complete specification of the accounting relationships in supply and use tables required to model output by disaggregated industry.

The parameters of the behavioural relationships in MDM-E3 are estimated econometrically over time, within limits suggested by theory, rather than imposed from theory. The economy is represented as being in a continual state of dynamic adjustment, and the speed of adjustment to changes (in, for example, world conditions or UK policies) is based on empirical evidence. There is therefore no assumption that the economy is in equilibrium in any given year, or that there is any automatic tendency for the economy to return to full employment of resources.

In summary MDM-E3 provides:

- annual comprehensive forecasts to the year 2020:
    - for industry output, prices, exports, imports and employment at an industry level; for household expenditure by 51 categories;
    - for investment by 27 investing sectors for the nine Government Office Regions, Wales, Scotland and Northern Ireland
- projections of energy demand and emissions, by 25 fuel users and eight main fuel types (in all, 11 fuels are distinguished)
- full macro top-down and industrial bottom-up simulation analysis of the economy, allowing industrial factors to influence the macro picture
- an in-depth treatment of changes in the input-output structure of the economy over the forecast period to incorporate the effects of technological change, relative price movements and changes in the composition of each industry's output
- scenario analysis, to inform the investigation of alternative economic futures and the analysis of policy

F2 Economy

The purpose of MDM-E3 is to abstract the underlying patterns of behaviour from the detail of economic life in the UK and represent them in the form of a key set of identities and equations. In a complex system, such as the UK economic system, the abstraction is very great. In any economic model the initiatives, responses and behaviour of millions of individuals is aggregated over geographical areas, institutions, periods of time and millions of heterogeneous goods and services into just a few thousand statistics of varying reliability. The aim of MDM-E3, then, is to best explain movements in the data and to predict future movements under given sets of assumptions.

A key contribution of the approach to modelling the UK economy in MDM-E3 is the level of disaggregation. The macroeconomic aggregates for GDP, consumers' expenditures, fixed investment, exports, imports, etc are disaggregated as far as possible without compromising the available data.

One reason for disaggregation is simply that it is necessary to answer certain questions of economic interest. Some macroeconomic questions are intrinsically structural and if they are to be answered using a model then it must be disaggregated in some way. The disaggregation of agents and products is crucial in trying to understanding the behavioural responses of heterogeneous agents as it reduces the bias encountered in estimating aggregate relationships.

The principal economic variables in MDM-E3 are:

- the final expenditure macroeconomic aggregates, disaggregated by product, together with their prices
- intermediate demand for products by industries, disaggregated by product and industry, and their prices
- value added, disaggregated by industries, and distinguishing operating surplus and compensation of employees
- employment, disaggregated by industries, and the associated average earnings
- taxes on incomes and production, disaggregated by tax type
- flows of income and spending between institutions sectors in the economy (households, companies, government, the rest of the world)

Some variables are also disaggregated by Government Office Region and Devolved Administrations. This applies particularly to value added, employment, wages, household incomes and final and intermediate expenditures. Prices are not typically disaggregated by region, because of data limitations.

F2.1 National Accounts

A social accounting framework is essential in a large-scale disaggregated economic model. The early versions of MDM were based on the definitions and estimation of a Social Accounting Matrix (SAM) for the UK and its associated input-output tables and time-series data. The principles of SAM have been extended and elaborated in detail in the UN's revised System of National Accounts (SNA). Accordingly we now use the SNA for the accounting framework for the data and the model.

The national accounts provide a central framework for the presentation and measurement of the stocks and flows within the economy. This framework contains many key economic statistics including Gross Domestic Product (GDP) and gross value added (GVA) as well as information on, for example, saving and disposable income.

The national accounts framework makes sense of the complex activity in the economy by focusing on two main groupings: the participants of the economy and their transactions with one another.

Units are the individual households or legal entities, such as companies, which participate in the economy. These units are grouped into sectors, for example the Financial Corporations sector, the Government sector and the Household sector. The economic transactions between these units are also defined and grouped within the accounts. Examples of transactions include government expenditure, interest payments, capital expenditure and a company issuing shares.

The national accounts framework brings these units and transactions together to provide a simple and understandable description of production, income, consumption, accumulation and wealth. These accounts are constructed for the UK economy as a whole, as well as for the individual sectors in the Sector Accounts.

Since 1998 the National Accounts have been consistent with the European System of National Accounts 1995 (ESA95). The ESA95 is the European implementation of the International System of National Accounts 1993 (SNA93) developed by the UN to ensure a common framework and standards for national accounts, including input-output analyses, sector accounts and constant-price analyses. The ESA95 was developed to reflect the changing role of government, the increased importance of service industries and the increased diversity of financial instruments. It recognises the wider scope of capital formation, by using concepts such as intangible assets.

F2.2 The Determination of Output

The determination of output in MDM-E3 can be divided into three main flows of economic dependence:

- the output-investment loop
- the income loop
- the export loop

Consumers' expenditure is estimated at an aggregated level for each of the 12 UK regions covered in MDM-E3 and then further disaggregated to the 51 expenditure categories which relate to the COICOP classification. At the aggregate level regional consumption in real terms is predominantly a function of regional real income.

This relationship is constrained to reflect the idea that expenditure cannot outgrow income levels in the long term, although it is possible in the short term. The other key drivers of regional consumption as defined in the equations are:

- the adjusted dwellings stock
- the OAP dependency ratio
- inflation

In the short run we also consider the effects of:

- unemployment - in the literature high levels of unemployment are linked to sharp falls in consumer spending beyond the fall in consumer spending which can be explained by an associated fall in real gross disposable income that the unemployment would cause; this is explained in the literature by the uncertainty that unemployment induces across a region

- real house prices - we assume here that there is a positive (negative) wealth effect caused by increasing (decreasing) real house prices which causes consumption to increase (decrease) in the short run

Regional consumption is then disaggregated further in the disaggregated regional equations which take the main independent variable as regional consumption, which effectively reflects the income effect on consumption (the parameter is restricted to be positive). The other explanatory variables are relative prices in the form of the price of each consumer category compared to the overall price index for all consumer items, this captures the price effect (the parameter is restricted to be negative). The OAP and child dependency ratios are also considered so as to reflect differing consumption patterns arising from changing demographic structure in the different regions.

For the consumption categories that represent energy products, consumption in each region is determined by applying the growth rate in UK fuel consumption (in energy units) from the fuel user 'households' (or in the case of petrol - road transport) to the real consumption of gas, electricity, coal, petrol and manufactured fuels. The fuel used by households and road transport is derived from the energy and transport sub-models described later. Disaggregated consumption is then scaled to match regional consumption at the aggregate level.

Household expenditure by expenditure category is then mapped to the 41 product categories to derive domestic consumer demand by product category.

Among other elements such as social-capital formation, public and private sector dwellings and legal fees, the most important element of gross fixed capital formation is the acquisition of new buildings, plant and machinery and vehicles by industry.

Investment in MDM-E3 is treated quite differently to the neoclassical framework which relies on the production function of firms and net present welfare maximisation based on equating the user cost of capital with the marginal product of capital.

However, the neoclassical treatment leads to an unresolved conflict between the implied costless switch between capital and employment and the observation that capital stock adjustments are subject to significant time lags.

In MDM-E3 investment data are divided into 27 investing sector categories at the national level. The national investment equations depend on industry output, which is converted from the 41 industry sectors to the 27 investing sectors. The equations yield the result that an increase in output will lead to an increase in investment. Typically, the investing sectors which are most responsive to changes in output are the capital-intensive manufacturing-based investment sectors such as Transport Equipment.

The investment equations are specified in the Engle-Granger co-integrating form and therefore allow for the impact of the lagged investment and an error correction term allowing adjustment to the long-term trend.

Assumptions for government capital spending are used to forecast gross fixed capital formation in the investing sectors relating to Health, Education and Public Administration. Government final consumption expenditure is treated exogenously in MDM-E3 and is based on the plans announced in the Comprehensive Spending Review and Budget statements.

Government revenues from taxes on income and production are inherently endogenous as they rely on consumption and incomes. This duality is an important consideration in scenario analysis. Increased tax revenues are not automatically recycled into the economy. Model operators must decide where additional revenue should be spent. If additional tax revenues are not spent they will, by definition, simply reduce the Public Sector Net Cash

Requirement (PSNCR), but this has no further effects on behaviour (for example, it is not assumed that household spending responds to the prospect of higher or lower taxation in future as indicated by the extent of government borrowing in the present).

MDM-E3 has assumptions for 19 world regions, covering (among other factors) activity (GDP), price levels and exchange rates. The world activity indices are the key drivers of export demand, which is estimated across the 41 product categories. The result is that an assumed change in US GDP growth will affect the products that are most traded with the US, depending on the weighting of US demand in the world demand for UK exports and the responsiveness of UK export demand to the change in the world activity index. The price of exports also affects the level of export demand. To explain historical export volumes two dummy terms for integration with the EU internal market are significant for 1974 and 1978.

Import volumes are determined by domestic demand and import prices relative to domestic prices. A capacity utilisation constraint is also considered in the short term.

Input-output supply and use tables (SUTS) provide a framework to make consistent estimates of economic activity by amalgamating all the available information on inputs, outputs, gross value added, income and expenditure. For a given year, the input-output framework breaks the economy down to display transactions of all goods and services between industries and final consumers (eg households, government) in the UK. Since 1992, ONS has used the input-output process to set a single estimate of annual GDP and ONS has published the detailed analyses in the SUTS.

The information from the regular releases of SUTS are used in conjunction with the more detailed analytical tables (last published for 1995) to construct the inputs that are required for the MDM model. An input-output table has been estimated from official data to provide the detail needed to model inter-industry purchases and sales.

The input-output coefficients derived from the SUTS allow intermediate demand to be derived for each product given the final demand at the product level of disaggregation.

The employment equations for MDM-E3 are based on a headcount measure of employment rather than on a full-time equivalent basis. The employment equations are specified by region and industry. The two main drivers of employment are gross output and the relative wage costs as measured by industry wages relative to industry prices.

Labour productivity is defined on a net output per job basis.

In MDM-E3 assumptions are made for world prices and exchange rates. These are then used to determine import prices, which are one element of the cost to the UK's industries of bought-in inputs. The other element is, of course, the cost of the UK's own production. Unit material and labour costs determine industry output prices. Consumer prices, then, depend partly on import prices and partly on UK industry prices, together with taxes on products. Consumer prices have an influence on average wage rates, as do labour market factors. Average earnings and productivity are then used to determine unit labour costs. Export prices depend partly on unit labour costs in the UK and partly on world prices (reflecting the extent to which prices are set in world markets).

Previous versions of MDM have sought to include endogenous treatments for interest rates and exchange rates but the inclusion of these specifications often led to increased instability within the model. Recent versions of the model therefore rely on an exogenous treatment for both exchange rates and interest rates. This has important consequences for scenario analysis. For instance, unilateral UK action on carbon taxes might push domestic consumer price inflation to a position where the Bank of England might take deflationary action by increasing the repo rate. Similarly, exchange rates do not change in response to domestic prices, the balance of payments, world prices, Treasury bill rates and so on.

Industrial prices are formed as a mark-up on unit costs with an allowance for the effect of the price of competitive imports, technological progress and, in the short run part of the equation, the effect of expected consumer price inflation. The supply side comes in through the utilisation of capacity as measured by the ratio of actual output to normal output.

For many of the industries the dominant effect is industrial unit costs. However, import prices can affect domestic prices in three different ways. First, by directly increasing industrial unit costs, to the extent that industry inputs are imported. Second, as competitor prices so that domestic prices tend to rise with import prices over and above any effect on costs. Third, as import prices directly affect consumer price inflation and therefore the expectation of future increases in import prices.

Import and export prices play the role of transmitting world inflation to the UK economy through its effect on export and import prices. Import and export prices are determined by world product prices, the exchange rate, world commodity prices and unit cost. For export prices in the short term there is also a supply-side effect which comes through the increases in the utilisation of capacity. A measure of technical progress is also included to cope with the quality effect on prices caused by increased levels of investment and R&D. Restrictions are imposed to force price homogeneity and exchange rate symmetry on the long-term equations.

Consumer prices are determined by import prices and industry prices and the respective weighting of imports and domestic purchases in consumers' expenditure, together with the application of product taxes.

The aggregate consumer price index is assumed to have a positive relationship with wages, such that an increase in prices should lead to an increase in wages. Productivity also has a positive relationship with wages: if employees in an industry are able to increase value added by increasing output for the same input then they are able to command higher wage rates.

The treatment of wages in MDM partly follows the typical wage bargaining model. The opportunity from not working as expressed by unemployment benefit has a positive relationship with wages as the benefit rate will mean that workers will want to gain sufficiently more than the available benefit transfer to justify employment. In MDM-E3, again following the wage bargaining models, unemployment levels also have an impact on wages: if unemployment is high it follows that wages will be low as there is no incentive for employers to pay an individual more when there are a large number of unemployed willing to work for a lower salary.

The retention ratio term identifies the average real take-home pay for any given salary level. The purpose of this is to simulate the characteristic of individuals operating in a way to make sure that their net pay means they are equally well off following a change in tax. If income tax increases, the retention ratio falls and wages rise to (fully or partially) compensate for the higher tax rate.

In an attempt to understand relationships between wages within one industry but across regions, or within one region but across industries, MDM-E3 also uses external industry wage rates and external regional wage rates to estimate wage rates as a system. The idea is that if wages in a region are increasing for all other industries that are not industry Y, then this should drive an increase in industry Y wages, within the specified region. This argument is then extended for one industry's wages across all the regions. If the oil and gas industry increases wage rates in all non-X regions, this will have an impact on the oil and gas industry wages in region X.

Wage bills are calculated across region and industry by multiplying the average wage by the number of full time equivalent (FTE) employees. Further key variables, such as the total wage bill, average wage, average wage for a region and average wage for an industry are also calculated.

The treatment of financial stocks and returns in the model is currently quite limited and they have no important effects.

F3 Energy

Flows in the economic model are generally in current and constant prices, prices are treated as unit-value indices, and the energy-environment modelling is done in physical units. This modelling is described in Barker et al (1995).

MDM-E3 includes a bottom-up (the ETM) sub-model to model changes in the power generation sector's use of fuels in response to policy initiatives and prices. This modelling approach has been reviewed by McFarland (2004) and has the advantages that it avoids the typical optimistic bias often attributed to a bottom-up engineering approach, and the unduly pessimistic bias of typical macroeconomic approaches. It was the focus of a recent Tyndall Centre project (Koehler et al., 2005) and the current research under the Energy Systems and Modelling Theme (ESMT) for the UKERC (Barker et al., 2005).

Energy-environment characteristics are represented by sub-models within MDM-E3, and at present the coverage includes energy demand (primary and final), environmental emissions, and electricity supply. Energy demand by industries is then translated into expenditure flows for inclusion within the input-output structure to determine economic variables, so that MDM-E3 is a fully-integrated single model, allowing extensive economy-energy-environment interactions.

The ability to look at interactions and feedback effects between different sectors - industries, consumers, government - and the overall macroeconomy is essential for assessing the impact of government policy on energy inputs and environmental emissions. The alternative, multi-model approach, in which macroeconomic models are operated in tandem with detailed industry or energy models, cannot adequately tackle the simulation of 'bottom-up' policies. Normally such multi-model systems are first solved at the macroeconomic level, and then the results for the macroeconomic variables are disaggregated by an industry model. However, if the policy is directed at the level of industrial variables, it is very difficult (without substantial intervention by the model operator) to ensure that the implicit results for macroeconomic variables from the industry model are consistent with the explicit results from the macro model. As an example, it is very difficult to use a macro-industry, two-model system to simulate the effect of exempting selected energy-intensive industries from a carbon or energy tax.

The energy sub-model determines final energy demand, fuel use by user and fuel, the prices of each fuel faced by fuel users, and also provides the feedback to the main economic framework of MDM-E3. Fuel use for road transport is solved using MDM-E3's Transport Sub-model. Fuel use for power generation is calculated in the electricity supply industry (ESI) sub-model, which uses a 'bottom-up' engineering treatment.

F3.1 Final Energy Demand

Final energy and fuel demand by fuel user is modelled by econometric equations, which are estimated using a standard cointegrating technique. The estimation of energy demand occurs in a two-step method. Firstly, the aggregate (ie with no breakdown by fuel type) demand for energy for each end-user is determined. Typically, the key dependent variables are:

- the activity of the fuel user, usually taken to be gross output of the sector, but, in the case of households, household expenditure is used
- technological progress in energy use, which reflects both energy-saving technical progress and the elimination of inefficient technologies
- the price of energy relative to general prices
- changes in temperature

In addition, to account for the Climate Change Levy and Climate Change Agreements, we also include the ‘announcement’ effect of the CCL and the ‘awareness’ effects on participating industries of the CCAs. The estimates of these effects were derived from a study by Cambridge Econometrics for HM Customs and Excise (Cambridge Econometrics, 2005).

Fuel users’ demand for each fuel is estimated by splitting the estimated aggregate energy demand. To reflect the fact that fuel switching is inhibited by the existing stock of appliances and machinery used in the economy and the available infrastructure, it is assumed that fuel users adopt a hierarchy in their choice of fuels:

choosing first electricity for premium uses (light, electrical appliances motive power, special heating applications)
then sharing out non-electricity demand for energy between three fossil fuels (coal and coal products, oil products and gas)

The specification of these equations is similar to that of the aggregate energy equations, except that the estimated variable is the fuel share, and the explanatory variables are:

- activity
- technology measure
- three price terms - the price of the fuel type in question, the price index of its nearest competitor, and the general price index within the economy
- temperature (where relevant)

This method is regarded to be the most suitable given the data available and the relative quality of data at different levels of disaggregation. The aggregate energy demand equations command a higher level of confidence than the fuel share equations. The estimated fuel share equations used to split aggregate demand to yield demand for individual fuels by fuel users fit the data better than equations which directly estimate the demand of a particular fuel by an individual fuel user. This is partly due to high level of volatility in the time series data at this level of detail.

Both the aggregate energy/fuel demand equations and the disaggregated fuel share equations are specified as cointegrating equations:

- the dynamic part of the equation provides short-term responses of energy demand
- the long-term response is captured in the long-term part of the equation, adjusted for the speed of adjustment term (or error correction mechanism)

The equations for final energy demand are estimated on the data in the Digest of UK Energy Statistics (DUKES).

The wholesale prices of fossil fuels such as coal, oil and gas are assumptions in MDM-E3. Wholesale prices are converted to consumer/retailer prices for each fuel user by applying appropriate levies and taxes.

F3.2 Power Generation

MDM-E3 models the stock of power generation capacity and the annual generation of power from this stock in response to changes to demand for electricity, fossil fuel prices, carbon prices and incentives to increase the use of renewables. Changes to the power capacity stock are modelled by the electricity technology sub-model (ETM). Estimation of generation from the capacity stock is modelled by the electricity supply industry (ESI) sub-model.

The ETM builds on earlier work by Anderson and Winne (2004). The ETM assumes the role of the national social planner whose objective is to derive a schedule of build of new capacity to meet expected demand. It chooses to build capacity from a range of generation technologies.

The key drivers in determining the capacity build are contemporaneous and future values of:

- the required supply margin, usually expressed as a percentage on top of winter peak demand (currently this is around 18%)
- the prices of generation fuels (largely fossil fuels)
- the carbon prices of generation fuels
- the capital costs of new build
- the maintenance costs of new plant
- the payments to generators from the Renewable Obligation (RO); only eligible renewable power generation technologies attract the payment
- learning curve effects
- the build time of new plant

The ETM considers learning effects, where the cost of building a particular type of new capacity falls as more of that capacity gets built.

The ETM uses cost minimisation of net present value (NPV) in order to determine the type of new capacity that is built. Coupled with the learning effects, this can cause the schedule of new build generated by the ETM to be dominated by one particular type of technology. This effect is tempered by constraints on the amount of new build that is permitted to occur and assumptions for the technology chosen for any existing announced new build.

The ETM allows the model to project the impact of the Renewables Obligation (RO) including the ‘banding’ of RO payments. The model considers the contemporaneous and expected future values of RO payments, which are entered as inputs.

Power generation is estimated by the electricity supply industry (ESI) sub-model. The ESI sub-model distinguishes the fuel burn and other characteristics of existing power stations and possible future stations, to allow for substitution on the basis of current fuel and carbon prices. The model adjusts these load factors up or down as more or less generation from these plants is required.

The ESI uses cost minimisation to decide the generation mix in any given year. In some cases, however, these load factors are constrained in accordance with non-economic factors such as regulations. For example, the Environment Agency’s regulations on emissions from coal and oil-fired power stations require that the load factors of plants with or without FGD should be adjusted as follows: plants without FGD have their load factor restricted while plants retrofitted with FGD operate at a higher load factor (in the ratio 2:1) than plants without FGD owned by the same power companies. The ESI also takes into account the impact of the Large Combustion Plant Directive.

The ESI sub-model also includes a separate treatment of combined heat and power (CHP). In the CHP sub-model that has been developed, it is assumed that CHP schemes are operated before other electricity demand is taken from the grid. Hence, the demand for heat and power from CHP schemes is derived in the model before the overall demand for power. The generation from CHP schemes is then subtracted from the overall demand for electricity to be met by the generating stations attached to the grid. The use of electricity from the CHP plants shows up as increased energy efficiency in overall electricity generation (because, as the proportion of CHP-generated electricity increases, the efficiency rises).

Electricity prices are endogenously derived and depend on the relative share of each fuel used in generation of power in the year. The value of renewable certificates and any carbon price are also passed through to the wholesale price. It is assumed that 100% of the costs of generation are passed though to the wholesale price. This is consistent with evidence of the ability of power generators to pass on the cost of the Phase 1 EU ETS carbon price to the wholesale electricity price (Ekins, 2005). The retail price of electricity faced by end users is calculated by the model, based on historical evidence. Large industrial users can be insulated from variations in the retail price as they may have bilateral contracts with suppliers to fix the price for a number of years.

Due to their characteristics and the nature of the UK electricity market, there are real-world constraints on the extent to which nuclear and intermittent forms of generation such as wind (without back up) can service the power needs of the UK, especially the daily and seasonal peaks in UK's electricity demand. However, the electricity sub-models in MDM-E3 do not incorporate these constraints; all available technologies are treated as perfect substitutes for each other. Coupled with the cost minimisation algorithm used to determine the capacity and generation mix for power generation, the effect can be that the proportion of capacity made up by intermittent forms of generation such as wind can be overstated.

F3.3 Road Transport

MDM-E3 now incorporates a transport sub-model to project energy demand from Road Transport. These results are used in place of the 'top-down' equations previously used, and which are still used to solve energy demand from the other final users. The projections for Road Transport are still derived from a set of econometrically-estimated equations but the degree of disaggregation is far greater, as is the number of explanatory factors considered. The treatment is sufficiently general that the other three modes of transport (air, rail and water) can also be modelled but these elements are not yet operational.

The sub-model is composed of three sets of stochastic equations to explain:

- the demand for travel, expressed in kilometres, disaggregated by vehicle type (eg Cars and taxis, Bus/coach and HGV) and network type (eg Rural A roads, Urban A roads and Motorways)
- annual purchases of new vehicles, disaggregated by vehicle type and technology (eg internal combustion engines that run on Petrol, Diesel or LPG)
- changes in the fuel efficiency of different vehicle categories, differentiated by vehicle type (eg the fuel efficiency of petrol-driven cars is allowed to differ from, and move differently to, the fuel efficiency of petrol-driven buses)

The sub-model contains a representation of the vehicle stock in which additions are determined by the second and third sets of equations and older vehicles are scrapped according to an exponential function such that the rate at which vehicles are removed from the stock increases with their age. The average fuel efficiency of the stock can thus be tracked over time and combined with the demand for travel to derive the demand for fuel in each year. The consequent emissions are calculated on an implied basis using the last year for which data on energy demand and emissions are both available.

The sub-model was designed by the Cambridge Centre for Climate Change Mitigation Research 4CMR based on a specification outlined in Johnstone (1995) and was implemented and integrated by teams at 4CMR and CE. The work was funded by the Green Fiscal Commission and the UK Energy Research Centre.

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Annex G: Additional Resources

Table 6.1 below illustrates the % of companies benefitting from support under the Envision Project which have implemented resource efficiency measures under different categories. However, a breakdown of these measures by sector and therefore the extent to which they have been implemented in the Food, Drink and Tobacco and Construction sectors is not available.

Table G1: Measures/Actions taken by companies following support from SWRDA Envision Project			
Energy Actions	**% co.s**	**Transport**	**% co.s**
Turning appliances off	20	Use public transport more	7
Monitoring energy use	11	Transport policy	7
Installing timer switches	4	Car share	5
Installing energy saving light bulbs	25	Monitoring of business miles	7
Adopting alternative heat sources	15	Cycling	5
Raising awareness	11	Better vehicle maintenance	2
Installing insulation	7	Driver training	2
Generating renewable power	5	Walk to work	2
Making buildings more efficient	2	AV technology	2
Upgrading to efficient equipment	5	Shipping goods better	2
Reducing thermostat settings	4	New buses	2
Redesigning building layouts	2		
Research into alternatives	5		
Setting KPIs	4		
Reducing raw materials		**Waste reduction**	
Avoid excess packaging		Waste separation	7
Reduce use of paper		Recycling of waste	47
Monitoring consumption		Composting	4
Reduced oil consumption		Specialist waste handling	9
Stop buying bottled water			
Consider environmental impact before purchasing anything			
Source: "An Economic, Environmental and Strategic Impact Evaluation of Envision", ESKOGEN for SWRDA, 2010			

Measures listed in the above table correlate with case study examples from the sector studies and indicate that the majority of enterprises turn to the use of recycling, energy saving light bulbs, switching-off and alternative heat sources as the main actions for quick-win resource savings.

According to the figures of Yorkshire Forward's resource efficiency improvement grant (BREIG), jobs are more likely to be retained than created. Within the programme a number of enterprises have been supported under different types of interventions as indicated in Table A1.2

Table G2: Number of Businesses Supported	
Intervention	**Total number of businesses supported**
Carbon management Clubs	20
Green Business Support organisation	254
Recycling Action	185
NISP	143
Why Waste	99
Total	701

Figures in Table G3 on the Summary of Gross Outputs 2006-7 can be used as comparison to the model of this study. Data are not sector specific and are reported as resulting outputs for a number of different types of intervention supports. However, the purpose of these interventions was to promote and support the adoption of resource efficiency measures at company level and predominantly focused on the “quick-win” type measures.

Table G3: Summary of Gross Outputs 2006-7					
	Jobs Created	**Jobs Safeguarded**	**Increase in Business Sales (£m)**	**Expected Business Investments**	**Expected Reduction in Costs**
Carbon Management Clubs	-	32.9	-	-	1.65
Green Business Support Organisation	-	-	-	-	1.79
Recycling Action Yorkshire	39	-	1.72	12.54**	0.58**
NISP	135	252	14.28	7.2**	0.61**
Why Waste	-	-	0.1**	0.6**	0.35**
Total	174	284.9	16.1	20.34	4.98
** Denotes figures that are based on survey data					