Material change for a better environment

Final report

# Meeting the UK climate change challenge: The contribution of resource efficiency

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WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

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# Executive summary

1. Waste & Resources Action Programme (WRAP) commissioned the Stockholm Environment Institute, University of York, to undertake this study to explore the contribution material resource efficiency (hereafter referred to as resource efficiency) and material sufficiency can make to meeting the Greenhouse Gas emission target of reducing emissions by 80% target by 2050.
2. Strategies for climate change mitigation require an understanding of both the technologies by which resources are transformed into products and the lifestyle choices that shape household use of such products (Duchin, 1998)[1]. This report investigates strategies for making the supply of, and demand for, materials and products in the UK more efficient. This is the first time supply chain emissions associated with all materials and products used by the UK economy have been accounted for in such a detailed consistent accounting framework. The model used for the study was developed by Stockholm Environment Institute and is the UK's most detailed "Multi-Regional Input Output Model". For more information on the model please visit www.sei.se/reap.
3. The report provided new evidence on the historical trends in UK GHG emissions from 1992 to 2004 describing in detail the complete global supply chain greenhouse gas impacts of all goods and services consumed in the UK over the past two decades. The key conclusions being:

   - Service sectors are substantial procurers of manufactured goods and are therefore deeply connected to primary and secondary industries. From a lifecycle perspective, service sectors are significant contributors to UK emissions. From a territorial perspective, the importance of service sectors is growing, re-emphasising the need to focus on strategies aimed at service sectors in the UK.
   - Comparing a territorial and consumer approach, the evidence strongly supports the claim that the UK is increasingly relying on carbon intensive manufacturing overseas to meet growing consumer demand.
   - Growth in the transport sector is the main driver behind rising $CO_2$ emissions. All other GHGs have been considerably reduced in the same time period from a territorial perspective.
   - At present, resource efficiency and sufficiency measures are not delivering the reductions required to reduce absolute emissions, and attention must be made to UK consumer patterns.
   - Accounting for the impact of imports reveals that the UK's contribution to climate change is increasing. There is little evidence to suggest that this situation will change in the short term.

4. The project findings provide new insights and broaden the range of options that can be considered by policy makers looking to reduce GHG emissions. The findings are based around four resource efficiency scenarios which draw on a wide range of supply and demand side strategies. Each scenario gives an insight into the percentage reduction in global GHG emissions that can be achieved through implementing resource efficiency strategies up to 2050. The four scenarios were:

   - Reference scenario – Takes into account both historical trends, and uses econometric modelling to suggest a plausible future for the UK economy.
   - Quick Win scenario – Identifies what can be achieved in the short term across all the resource efficiency strategies using the time period of 2010 to 2020 (continuing to 2050 at the same level). These strategies are defined as being relatively easy to implement as they do not require additional costs or major technology and or cultural shifts.
   - Best Practice scenario – Identifies the possible reductions in GHG emission that could be achieved if the best currently available technologies and consumption behaviours were adopted across all appropriate sectors and households by 2050.
   - Beyond Best Practice scenario – The scenario provides an insight into the maximum potential of the resource efficiency strategies assuming that all major barriers could be removed so that the strategies could recognise their full potential. The scenario timeline is until 2050.

5. The starting point for the Reference scenario assumptions is a wide range of historical economic data that is collected at a highly disaggregated level and covers all the major economic indicators. The majority of this data comes from the Office of National Statistics (ONS). Data also comes from a number

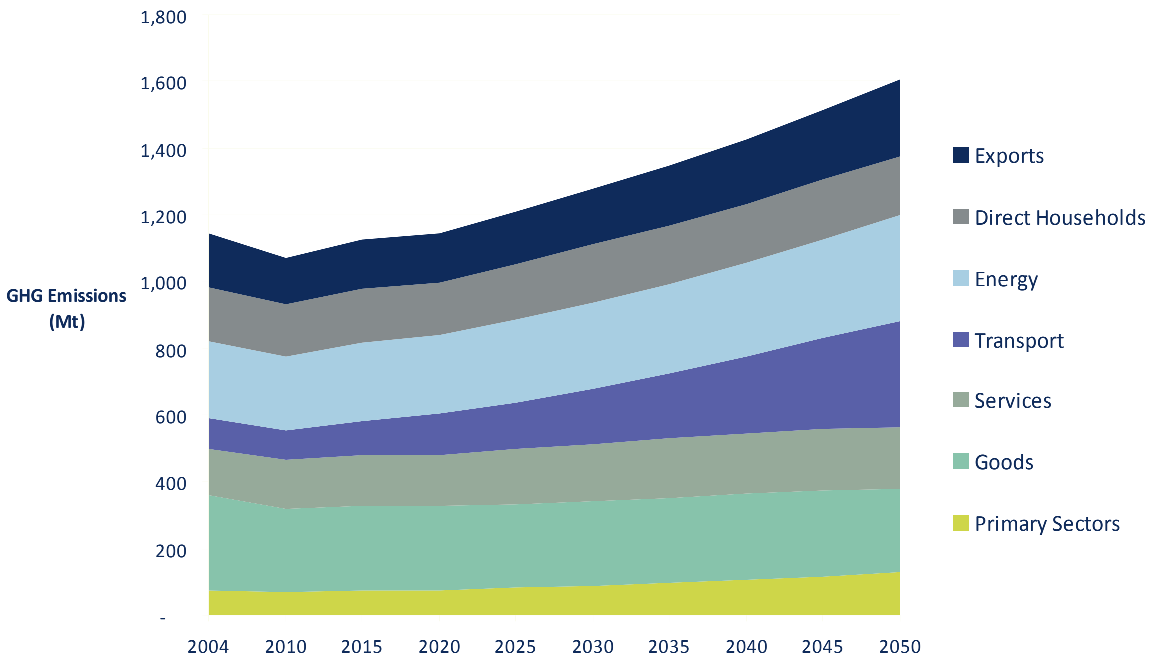
[1] *Duchin, F. (1998) Structural Economics; Measuring change in technology, lifestyles and the environment, Washington D.C.: Island Press.*

of other sources including the Labour Force Survey, the CBI's survey of manufacturing industries, and the European Commission's survey of consumer confidence.

Our Reference scenario suggests an increase in UK consumer GHG emissions between 2004 and 2050 from 1 billion to 1.37 billion (an increase of 40%). This represents an annual growth rate in emissions of approximately 0.7% per year, which is very much in line with historical growth in UK consumer emissions that showed a 9% growth over the past 14 years. UK territorial emissions are estimated to grow by 34% from 0.73 billion to 0.98 billion tonnes of GHG emissions. There is growth in both imported emissions and territorial emissions for UK consumption, although the growth is higher for imported emissions where a 50% growth between 2004 and 2050 can be seen, compared to 32% domestically.

Results are shown for the reference scenario broken down into highly aggregated sectors. The transport sector shows the greatest growth out of all the sectors.

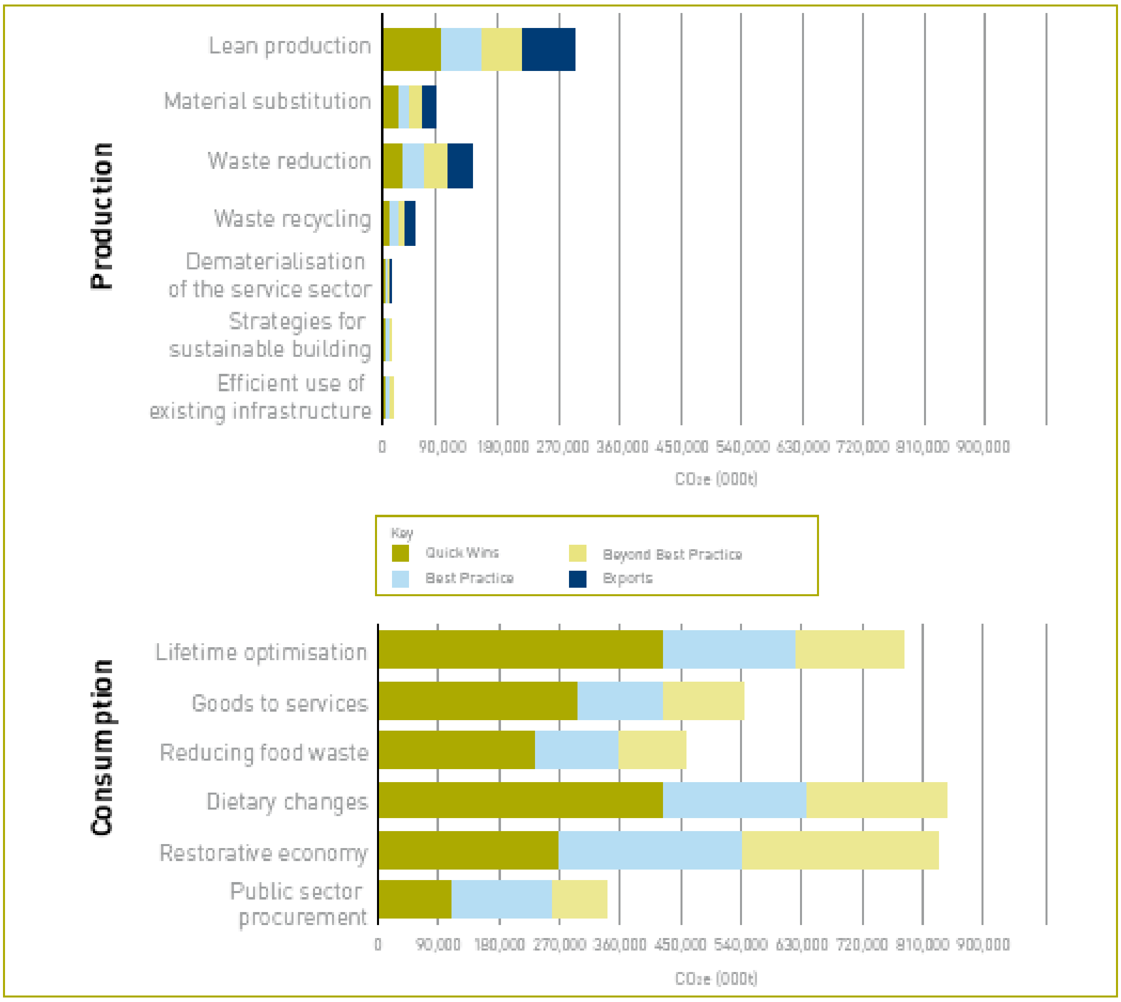
Figure a: Reference Scenario –UK Consumer Emissions (2004 to 2050)




6. Cumulative UK consumer emissions for the time period 2010 to 2050 indicate the total concentration of GHG emissions in the atmosphere induced by consumption in the UK. Assuming the UK needs to achieve an 80% reduction in consumer emissions, we can use this to derive the UK's carbon budget (the total GHG emissions the UK can release into the atmosphere each year until 2050). The total UK carbon budget by 2050 would therefore equal 22 billion tonnes (from a consumer perspective). If the UK takes no action to reduce emissions, the analysis estimates that any emissions released from UK consumption beyond 2031 are additional to the UK's carbon budget.
7. All the scenarios were made up of a range of strategies on the supply and demand side. The report documents the individual potential for success of the strategies as well as documenting the combined scenarios (i.e. the collective contribution). Details of each of the strategies are documented in the report along with the assumptions for each scenario.
8. The results for each of the individual strategies can be seen in figure b below. The production strategies that were most effective relate somewhat to the number of sectors that the strategy applies to. For example, the reductions were small in the strategies that related exclusively to the construction sector, compared to Lean Production which affected a wide range of sectors, including construction. Lean Production refers to reducing the amount of material in a product whilst maintaining its effectiveness, also known as "right-weighting".

9. Consumption side strategies deliver significantly larger savings. One of the key reasons for this is that consumption side strategies had the ability to affect emissions both in the UK and those associated with imports. As imported emissions are likely to account for over 45% of the UK total GHG emissions by 2050, any strategy that reduces the impact of imports will clearly achieve greater levels of reduction.

Figure b: Cumulative GHG emission reduction in production and consumption material sufficiency strategies to 2050, taking into account emissions from a consumption perspective.




10. There is considerable scope for reducing emissions by ensuring that households use material goods for their intended life and do not dispose of the product while they are still useful. Lifetime Optimisation is one the most successful strategies and concentrates on reducing the gap between psychological and technological obsolescence. The Restorative Economy can be seen as an extension of this strategy by building better products that last longer. Additionally, dietary changes that reduce the consumption of the most carbon intensive food products deliver a substantial saving, mainly because of reduced methane emissions from livestock. Changing diets to reduce meat consumption can save 846 million tonnes and ensuring that edible food is not treated as waste, a GHG emission reduction of about 456 million tonnes is possible by 2050.
11. Using the example of food waste, there is a clear advantage in terms of reduced amount of GHG emissions in the atmosphere through early implementation. This example shows the cumulative emissions saving of avoiding all edible food waste by 2050 (Best Practice) compared to fulfilling this intervention 20 years earlier by 2030 (Beyond Best Practice). Both scenarios achieve the same goal, the difference being the final year by which this goal is achieved. Early implementation (i.e. Beyond Best Practice) prevents an additional 100 million tonnes of GHG emissions in the atmosphere by 2050. Therefore, if over the next 20 years households in the UK didn't throw away edible food, a total of nearly 0.5 billion tonnes of GHG emissions would be avoided. If implementation was delayed, these additional emissions would need to be reduced somehow, showing a clear message that immediate action will make it easier for the UK to meet its ambitious targets by 2050.

12. In terms of the combined scenario, from a cumulative emission perspective, the Quick Win scenario would ensure a total GHG emissions saving of 1.8 billion tonnes by 2050 (4%). If Best Practice was achieved across all the goods and service sectors, this would deliver savings of 2.7 billion tonnes (6%). Finally, the Beyond Best Practice scenario would deliver savings of 3.5 billion tonnes (8%) by 2050, almost double that of the Quick Wins. While this may seem small, it is important to recognise that the study did not explore the savings in raw material sectors, transport or energy sectors. Instead it concentrated on the production of goods and services that account for 32% of total emissions by 2050. To get a clearer perspective on the scale of change achieved, we look exclusively sectors that were affected by the measure. From the goods and service sectors, the quick win scenario delivers savings of 9% by 2050. The best practice provides a saving of 22% and beyond best practice a saving of 28%.
13. In terms of territorial accounting, implementation of the 13 strategies, achieves a 2% reduction from the UK Territorial Reference Scenario if all Quick Wins were effective. Achieving Best Practice increases this reduction to approximately 3%, and at most they can achieve just over 4%. The UK Low Carbon Transition Plan sets out a roadmap for achieving an intermediate GHG emissions reduction goal of 18 percent to 2020 from 2008 levels. If the Quick Win strategies were achieved by 2020, resource efficiency improvements could deliver 9% of the required reduction.
14. In conclusion, Material Efficiency alone cannot deliver an 80% reduction in GHG emissions by 2050. However, it could clearly be part of an overall strategy that additionally recognises the need to decarbonise the electricity sector and achieve deep cuts in the transport sector. The necessary change is so substantial that every sector has to respond to the climate change crisis, including the product sectors. In the short-term, whilst infrastructural barriers prevent energy realising substantial emissions reductions now, there is a strong advantage for resource efficiency to deliver immediate savings. This would delay the time scale for the UK using up its carbon budget, and reduce the scale of reductions needed beyond 2020.
15. While the study demonstrates a significant advancement in applying a consistent methodology, the analysis was undertaken in am extremely tight deadline. Further research and evidence is required in specific areas.

    - There is a lack of evidence on the possible changes in resource efficiency within industry. This study would have benefited from a greater insight into the role of industry in resource efficiency and the potential for change. There is a need for detailed industry knowledge to understand the feasibility of resource efficiency strategies in individual sectors, thus creating a better understanding of the role of resource efficiency inside government
    - While all these strategies can be implemented with no significant effect on the overall UK economy, each strategy will cause a structural shift in the economy and there will clearly be winners and losers. National support is needed for industry and consumers to achieve this transition towards a low carbon economy.
    - A greater knowledge of the right policies to counteract the re-bound is required to ensure that all the resource efficiency and sufficiency strategies have their intended effect.

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# Glossary

**Consumption level:** Level of consumer spending (£)
**Consumption basket:** The proportion of consumer spend on products
**Eco-velocity indicator:** The 'eco-velocity' indicator developed by Nansai et al. (2007) examines the two most fundamental drivers of GHG emissions over time: rates of consumption growth and the GHG intensity of production. Eco-speeding is the term used to identify products where growing levels of consumption are offsetting emissions saved through production efficiency improvements leading to a rise in emissions.
**Final demand:** Final demand includes consumption by households, government and not for profit institutions servings households
**GHG:** Greenhouse gas emissions, measured in $Co_2e$.
**IPAT:** The equation developed by Ehrlich and Holdren in the early 1970s that states that an Environmental impact (I) is driven by Population (P), Affluence (A) and Technology (T).
**Multi-regional input-output model (MRIO)**: A MRIO model assigns emissions produced throughout complex global supply chains to final products
**OECD**: Organisation for Economic Co-operation and Development
**Product groups:** Product groups are the goods and services consumed by households and government. They are defined according to the Standard Industrial Classification system, which disaggregates the UK economy into 123 product groups.
**Production intensities:** The GHG emissions released to produce a unit of output by product groups
**Production structure:** The production structure of the economy represents interactions between all sectors in an economy. In this study these are the monetary transactions between sectors. This shows the inputs to each sector.
**SDA:** A structural decomposition analysis determines how changes in different components of population, affluence and technology have driven emissions changes over time (1992 to 2004 in this report)
**SEI:** Stockholm Environment Institute
**Standard Industrial Classification (SIC):** The Standard Industrial Classification of Economic Activities classifies business by the type of economic activity they are engaged in. This is currently disaggregated into 123 categories.
**UK consumer emissions:** Emissions released globally to satisfy all final demands in the UK, including direct household emissions. Therefore the model considers all the GHG emissions generated in other countries from the production of goods and services imported to the UK and excludes emissions from the production of UK exports.
**UK territorial emissions:** Emissions released by UK industries for the production of goods and services consumed domestically and overseas and emissions released directly by households (i.e. includes emissions embodied in UK exports). The overall emissions correspond to those reported in the UK Environmental Accounts and form the basis of the majority of climate change agreements. Included in our model is the emissions associated with international aviation and shipping, the two sectors excluded from the Kyoto Protocol.
**WRAP:** Waste & Resources Action Programme.

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# 1.0 Introduction

The UK Government's Climate Change Act (2008) commits the UK to reducing its territorial Greenhouse Gas Emissions (GHG) to 80% of 1990 levels by 2050. The Low Carbon Transition Plan sets out a roadmap for achieving intermediate goals over the next 10 years, with a particular focus on the energy sector. To achieve the long term 80% target, options need to be developed that explore what more can be done. These options need to take account of ways of improving all elements of resource use.

Waste & Resources Action Programme (WRAP) commissioned this study to explore the contribution material resource efficiency (hereafter referred to as resource efficiency) and material sufficiency can make to meeting the 80% target by 2050. As realistic strategies for mitigating the impact of climate change require an understanding of both the technologies by which resources are transformed into products and the lifestyle choices that shape household use of such products (Duchin, 1998)[2], this report investigates strategies for making the supply of, and demand for, materials and products in the UK more efficient. To our knowledge this is the first time supply chain emissions associated with all materials and products used by the UK economy have been accounted for in such a detailed consistent accounting framework. It includes emissions associated with material flows within the UK economy and efficiencies of production, and also the global emissions induced by UK consumption from both domestically produced and imported goods and services.

The project findings provide new insights and broaden the range of options that can be considered by policy makers looking to reduce GHG emissions. The findings are based around four resource efficiency scenarios which draw on a wide range of supply and demand side strategies. Each scenario gives an insight into the percentage reduction in global GHG emissions that can be achieved through implementing resource efficiency strategies up to 2050.

## 1.1 Defining resource efficiency

In the broader sense, resource efficiency is closely interlinked with sustainable development and as such has almost as many definitions, making it very important to define the term in the context of this study. The United Nations (UNEP) definition refers to resource efficiency as,

> *…reducing the environmental impact of the consumption and production of goods and services over their full life cycle* (Cropper, 2009[3])

Cropper refers to maximising the use of natural resources whilst minimising the depletion of natural capital and any pollution associated with that resource use at all lifecycle stages. Resource efficiency means using less materials and goods to provide the same output, for example a drinks bottle, a house or a car. Resource sufficiency relates to reducing the need for the material or product, such as doing without the car.

As the project has taken a full life cycle approach this definition works well. We trace GHG emissions through the full supply chain from raw material extraction through to production, transportation, use and disposal. Using the least possible material and energy input at each stage is central to resource efficiency.

WRAP works to encourage and enable businesses and consumers to be more efficient with their use of materials. This report therefore concentrates on the supply of and demand for materials and the implications for climate change targets. As such, it excludes detailed energy interventions. Due to the important role of energy in reducing emissions, changes in energy supply and demand are considered in the reference scenario, and output

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[2] *Duchin, F. (1998) Structural Economics; Measuring change in technology, lifestyles and the environment, Washington D.C.: Island Press.*

[3] *Cropper A. (2009) Decoupling Economic Growth from Environmental Degradation – The Crucial Role of Resource Efficiency, speech notes to the Resource Panel of the United Nations of the Division of Technology, Industry and Economics. Available from: http://www.unep.fr/scp/rpanel/pdf/opening_angela_cropper.pdf*

from the UK Energy Research Centre (UKERC) Energy 2050 scenarios[4] is used to provide household transport and home energy data. However, changes in energy generation beyond known policies are not within the scope of this project. This report attempts to fill an important gap in the evidence base by looking beyond energy to focus on the role of materials and products in relation to climate change.

## 1.2 Project aim and objectives

The overall aim of this project is to understand the contribution resource efficiency and sufficiency can make to the 80% GHG emission reduction target by 2050. The term "sufficiency" has been included to describe some scenarios that would reduce consumption in particular product groups. The scenarios documented in this report are set in the context of historical trends and known policies for the future. This reflects the project objectives which were to:

1. Document and analyse changes underlying the historic trends of UK GHG emissions from 1992 to 2004 in the context of resource efficiency[5];

2. Model a reference scenario to project UK consumer emissions to 2050 following a 'continuing trends' assumption whereby we continue along the historical resource efficiency pathway with known policies taken into account;

3. Identify and model three alternative resource efficiency and sufficiency scenarios of low, medium and high intervention to reduce UK emissions. The scenarios cover quick win interventions where cost savings can be made as well as interventions that require significant investment, infrastructure, technological development and cultural shift. Interventions refer to technologies and strategies for emission reductions covering resource efficiency of industrial sectors, resource efficient behaviours and imported emissions.

## 1.3 The role of resource efficiency in climate change

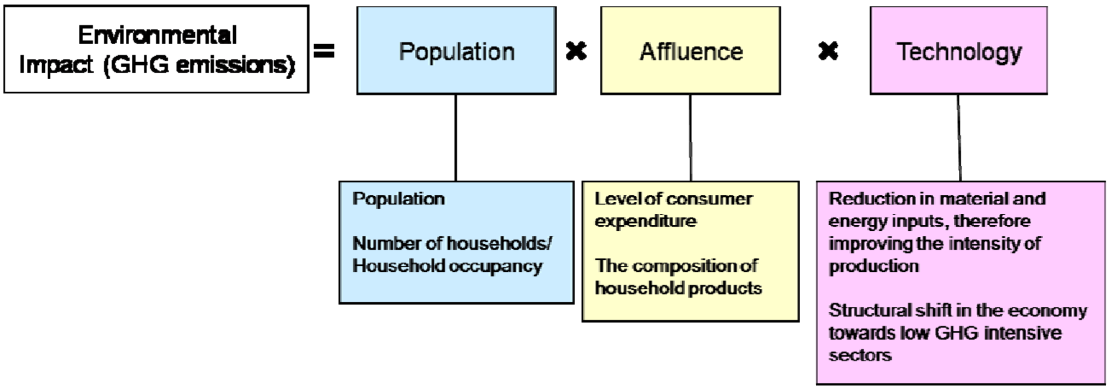
A useful understanding of the connection between environmental impact and resource efficiency is the *IPAT* equation developed by Ehrlich and Holdren in the early 1970s (Environmental impact (I) = Population (P) × Affluence (A) × Technology (T)). The equation implies that if improved resource efficiency measures are to prevent any further increase in emissions of greenhouse gases, the rate at which impacts are reduced through efficiency improvements must exceed the rate of consumption growth. In the UK over the past few decades we have seen two competing trends. Since the late 1980s the UK witnessed a large increase in the level of consumption expenditure and the average propensity to consume, common to many industrialised countries (Attanasio and Weber, 1994[6]). At the same time, technological advances have meant that we can produce products with greater efficiencies. By expanding the components of affluence and technology we can see the different mechanisms that exist to decarbonise the UK economy (illustrated in Figure 1).

[4] *Direct household emissions projections have been extracted from the UK MARKAL model and a comparison of results included (reference)*

[5] *The model used in the analysis is only available for the time period 1992 to 2004*

[6] *Attanasio, O. and Weber, G. (1994) The UK consumption boom of the late 1980s: aggregate implications of micro-economic evidence, The Economic Journal, 104, 1269 – 1302.*

Figure 1: Drivers of UK GHG Emissions (adapted from Ehrlich and Holdren, 1971).




Improved resource efficiency dominates climate change policies, whereby we can improve our current standard of living whilst reducing the use of resources. A common assumption is that a 1% increase in efficiency will lead to a 1% reduced need for the resource. This assumption has been challenged as efficiency gains can cause a reduction in the price of products and raise demand for the resource. Alternatively, the reduced cost may mean the consumer has more money to spend on other goods and services - potentially carbon intensive goods and services. This phenomenon is commonly referred to as the rebound effect. The first part is known as a direct rebound effect, the latter part as an indirect rebound effect (Sorrell, 2007[7]; Schettkat, 2009[8]).

Evidently, resource efficiency gains cannot guarantee the overall goal of a low carbon economy, and influencing the demand side is therefore another prerequisite. As pointed out by Angela Cropper, the Deputy Executive for UNEP,

> *It will only be by a combination of resource efficiency and resource sufficiency measures that the ultimate goal of sustainable consumption and production patterns can be achieved* (Cropper, 2009)

The rebound effect, or the fact that resource efficiency measures sit within a wider policy framework does not delegitimise it in any way.

The famous publication "Factor Four" [9] identifies that doubling efficiency would lead to improved quality of life around the world and outlines measures which demonstrate the potential for this. Hawken et al. (1999[10]), suggest that ninety percent improvements in resource efficiency are not unrealistic and technological improvements can transform our use of resources, even with the economic and technology trends in place today. Whether or not ninety percent improvements with current technologies is unrealistic, there is clearly considerable potential for substantial improvements in resource efficiency.

## 1.4 What does an 80% reduction mean for the UK?

The approach currently adopted by the UK Government to measure its GHG emissions is based on a territorial approach defined under the Kyoto Protocol. This assumes that the UK is responsible for any emissions that occur within its borders, with the exception of emissions from aviation and shipping. There are well documented limitations with emission reporting under Kyoto, and this is acknowledged by the IPCC report which states

[7] *Sorrell, S. (2007) The Rebound Effect: An assessment of the evidence for economy-wide energy savings from improved energy efficiency, Sussex Energy Group, University of Sussex.*

[8] *Schettkat, R. (2009) Analyzing Rebound Effects, Schumpeter Discussion Papers, Schumpeter School, University of Wuppertal.*

[9] *Von Weizsacker E., Lovins A. and Lovins L. (1997) Factor Four – Doubling Wealth, Halving Resource Use, Earthscan Publicayions Ltd..*

[10] *Hawken, P., Lovins, A.B. and Lovins, L.H. (1999) Natural Capitalism The Next Industrial Revolution, Earthscan Publications Ltd, London.*

*Stabilisation of greenhouse gas concentrations requires substantial emissions reductions, well beyond those built into existing agreements such as the Kyoto Protocol (*IPCC, 2007[11])

In the UK, emissions from aviation and shipping alone accounted for 11% of the UK's total territorial emission account in 2004 and with unprecedented growth in aviation, will become a major source of $CO_2$ emissions in the future (Anderson et al., 2008[12]).

Besides the exclusion of these emissions, there are other limitations associated with territorial-based emission accounting. Countries are able to shift carbon-intensive production abroad, and therefore the emissions become the responsibility of the new country in which production takes place. This is particularly a problem when intensive processes are being shifted from developed countries with binding targets under the Kyoto Protocol, to countries that do not have binding targets (i.e. non-Annex countries). Approximately 25% of industrialised country's emissions are embedded in imports (Peters and Hertwich, 2006[13]). Recent research has shown that around 5 Gt of $CO_2$ is embedded in the international trade of goods and services, most of which flows from non-Annex I to Annex I countries (Peters, 2008[14]), presenting a serious problem to Kyoto signatories in the developing world and undermining the effectiveness of environmental policies (Peters and Hertwich, 2008[15]).

This report informs us about the GHG emissions released throughout the world during the production of goods and services consumed in the UK. This form of consumer based GHG emission accounting has been prominently discussed under the notion of "carbon footprinting". The UK's consumer emissions include the GHG emissions released abroad in the production of imports to the UK and excludes GHG emissions from UK exports. Put differently, instead of summing up the GHG emissions of all emission sources (factory chimneys, car exhausts) on UK soil, it traces the GHG emissions throughout the global supply chain of all products consumed in the UK. Figure 2 gives an insight into how this affects UK emissions.

Between 1992 and 2006, the UK reduced its GHG emissions that were included under the Kyoto protocol by 14%. However, these are not full territorial emissions as they exclude shipping and aviation. If these emissions were included, then the UK would have still reduced their overall emissions, but the reduction would have been 9% instead of 14%. From a consumer perspective (production – exports + imports), a very different pattern occurs. The UK's consumer emissions have grown by 9% between 1992 and 2006. There is a major concern that carbon accounting under the Kyoto Protocol has included the areas where emission reduction has been achieved and excluded the areas where a growth in emissions has occurred.

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[11] *Rogner, H.-H., D. Zhou, R. Bradley. P. Crabbé, O. Edenhofer, B.Hare (Australia), L. Kuijpers, M. Yamaguchi, 2007: Introduction. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.*

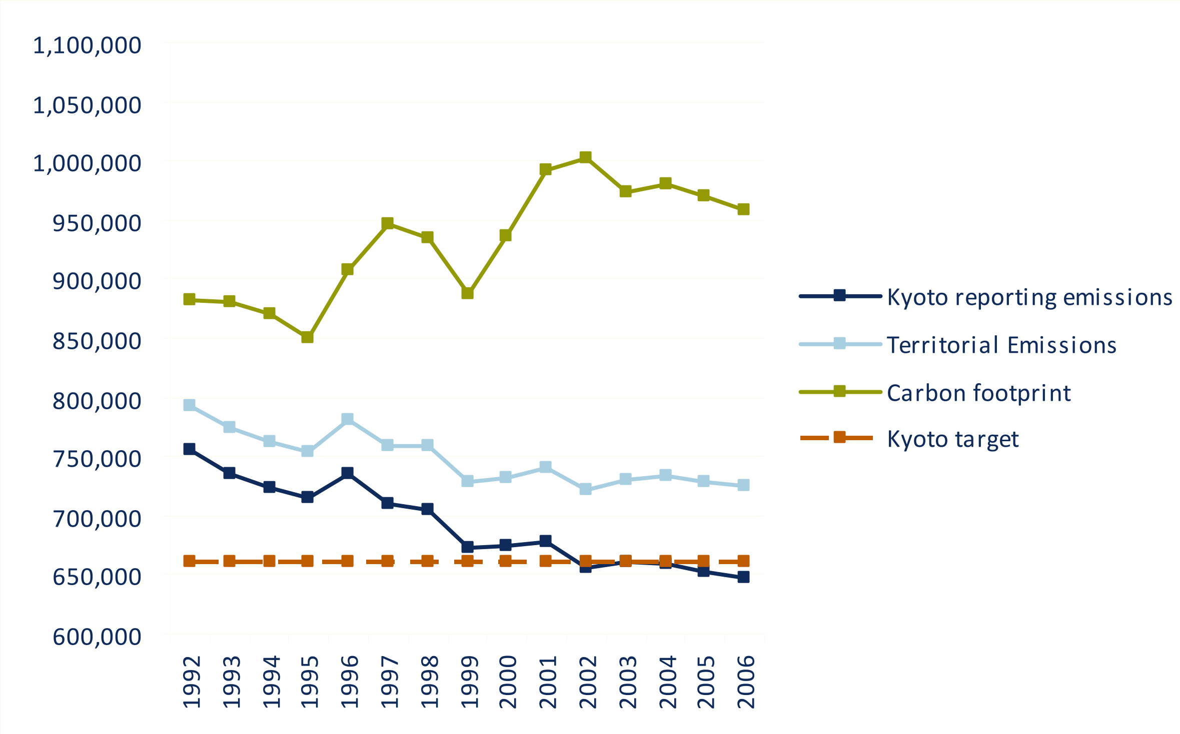
[12] *Anderson, K., Bows, A. and Mander, S. (2008) From long-term targets to cumulative emission pathways: Reframing UK climate policy*, Energy Policy, *36, 3714 – 3722.*

[13] *Peters, G. P. and E. G. Hertwich (2006) Structural analysis of international trade: Environmental impacts of Norway,* Economic Systems Research, *18 (2) 155-181.*

[14] *Peters, G. (2008) From production-based to consumption-based national emissions inventories,* Ecological Economics, *65, 13-23.*

[15] *Peters, G.P. and Hertwich, E.G. (2008) CO2 embodied in international trade with implications for global climate policy,* Environmental Science and Technology, *42 (5), 1401-1407.*

Figure 2: UK GHG Emissions, 1992 to 2004




If achieved, the 80% target will bring the UK's per capita territorial emissions down to roughly what would be allocated if global emissions were shared out on a population basis in 2050. This is an ambitious target and if reached would mean that on a per capita basis the UK would create only 2 tonnes of $CO_2e$ emissions per person.

The difference between territorial emissions per capita and consumption emissions per capita is currently over 4 tonnes per person. Each person is accountable for an extra 4 tonnes of GHG emissions if all indirect and import impacts are included. If this difference is maintained over the next 40 years, then consumer emissions per capita could be over 6 tonnes per person in 2050.

This concern may be unsubstantiated if global territorial emissions reductions for all countries was successfully implemented. If this was the case global emissions would reduce in line with targets and as a result the emissions from imports in the UK would be considerably reduced by efficiency improvements in those countries where the goods originate. This is clearly the ideal situation. However, if a global agreement to reduce territorial emissions isn't confirmed then it could become important for the UK to consider its emissions from trade and supply chain activities in the future.

## 2.0 Summary of methods

To understand the contribution of resource efficiency and sufficiency strategies to meeting UK 80% emissions reduction targets we conducted a scenario analysis to look at potential changes in material flows within the UK economy up to 2050, and the implications for GHG emissions. The project involved three distinct methodological stages, summarised in this section. First, we analysed historic trends, which formed part of the evidence base for developing the scenarios. The second stage involved generating the scenario descriptions, drawing on the historic trends and available evidence; for example, expert opinion, government reports and academic journals. Third, we quantified and modelled the potential impact of the scenarios on GHG emissions relating to UK consumption in one consistent modelling framework.

### 2.1 Scenario analysis

Scenarios are an important, if not essential, tool in devising future strategies for the low carbon economy. They give an indication of what the future might look like under a set of assumptions. Many authors document considerable uncertainty in predicting the future (for example see Smil, 2000[16]; Bishop et al., 2007[17]; Borjeson et al., 2006[18]). Scenarios are not predictive; they describe futures that *could be* rather than what *will be*. Our ability to project the future is highly constrained, and scenario analysis developed as a means of exploring alternative futures (Mander et al., 2008[19]).

Scenarios allow us to scope out possible future developments and evaluate how alternative courses of action would play out in terms of emissions, and as such play an important role in environmental policy. They can help generate long-term policies, strategies, and plans, which help bring desired and likely future circumstances in closer alignment (Glenn and the Futures Group International, 2003[20]). The emissions scenarios developed for the International Panel on Climate Change are a powerful example of this (Hertwich, 2005[21]), where the scenarios evaluate the climatic and environmental consequences of future global GHG emissions and assess alternative mitigation and adaptation strategies.

Through scenario analysis we attempt to identify the economic and environmental value to the UK of improving resource efficiency and sufficiency to 2050. We make informed decisions about potential changes in material resources in the UK in the future, based where possible on available evidence. Scenarios will always be open to debate as they are attempting to model the unknown, yet they do serve as relevant illustrations answering *what if* questions (Guan et al., 2008[22]). Due to the uncertainty attached to scenarios we aim to be as transparent as possible in documenting our data and assumptions.

### 2.2 Analysis of historic trends

We used an environmentally-extended multi-regional input-output model (MRIO) to understand historic changes in UK emissions from 1992 to 2004 (the time period for which the data is available). A unique strength of the

[16] *Smil, V. (2000) Perils of long range energy forecasting: reflections on looking far ahead,* Technological forecasting and social change, *65, 251 – 264.*

[17] *Bishop, P., Hines, A. and Collins, T. (2007) The current state of scenario development: an overview of techniques,* Foresight, *9(1), 5 – 25.*

[18] *Borjeson, L., Hojer, M., Dreborg, K., Ekvall, T. and Finnveden, G. (2006) Scenario types and techniques: Towards a user's guide,* Futures, *38, 723 – 739.*

[19] *Manders, S., Bows, A., Anderson, K., Shackley, S., Agnolucci, P. and Ekins, P. (2008) The Tyndall decarbonisation scenarios- Part 1: Development of a backcasting methodology with stakeholder participation,* Energy Policy, *36, 3754-3763.*

[20] *Glenn, J., and The Futures Group International (2003) 13. Scenarios, Ac/UNU Millennium Project, Futures Research Methodology – V2.0.*

[21] *Hertwich, E. (2005) Life Cycle Approaches to Sustainable Consumption: A Critical Review,* Environmental Science and Technology, *39(19), 4673.*

[22] *Guan, D., Hubacek, K., Weber, C., Peters, G. and Reiner, D. (2008) The drivers of Chinese $CO_2$ emissions from 1980 to 2030,* Global Environmental Change, *18, 626-634.*

model is that it distinguishes production technologies in different regions, in this case the UK and OECD European countries, OECD non-European countries and non-OECD countries. A car bought in the UK could have had its engine produced in Japan, the fabric for its seat covers made in China and its steel frame manufactured in Germany. A MRIO model acknowledges the difference in carbon intensities of production in the different world regions and assigns absolute emissions to the final product[23] based on these differences. It acknowledges that imported products consumed by UK residents might have been produced in a more (or less) carbon intensive process than would have been if produced domestically, allowing us to disaggregate emissions to particular regions, products and consumers.

This model is extensively documented in Wiedmann et al. (2008a[24]), accompanied with a sensitivity analysis, Wiedmann et al. (2008b[25]), and has been updated to include all GHGs. It is the most detailed model to our knowledge in the UK which can assess the full global supply chain impact of products consumed in the UK over time, and the output is used extensively by Defra to target policy interventions and monitor change at the national level.

Using a technique called structural decomposition analysis (SDA) we determined how changes in different components of population, affluence and technology have driven emission changes between 1992 and 2004. We investigate the effects that population, household size, intensities of production, production structure (i.e. material flows through the economy), consumption levels and the pattern of products consumed have historically had on UK emissions. In a report for DEFRA (*not yet published*), the Stockholm Environment Institute (Minx et al., 2009[26]) carried out a SDA to determine the key drivers behind changes in the UK's global and territorial carbon dioxide emissions from 1992 to 2004, which we have extended to include all GHGs.

In the analysis we also applied the 'eco-velocity' indicator developed by Nansai et al. (2007[27]) to examine the two most fundamental drivers of GHG emissions over time: rates of consumption growth and the GHG intensity of production, indicating whether industry efficiency measures are sufficient to mitigate GHG emissions.

## 2.3 Generation of scenario descriptions

To develop the scenarios we adopted a participatory approach based on expert input to brainstorm emission reduction strategies, bringing together a wider range of knowledge and disciplines. Five experts drawn from different departments in WRAP and two experts each from SEI, AEA Technology and Experian were involved in the scenario development process. The historical analysis was used to identify significant product groups and emissions drivers, which helped prioritise interventions both where WRAP has influence and where opportunities exist to make significant reductions.

A scenario framework was established to ensure that expert opinion on resource efficiency was fed directly into the development of the scenarios. This is outlined in Figure 3.

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[23] *The economy is classified into 123 product groups, determined by the Standard Industrial Classification system used by National Accounts, http://www.statistics.gov.uk/methods_quality/sic/contents.asp.*

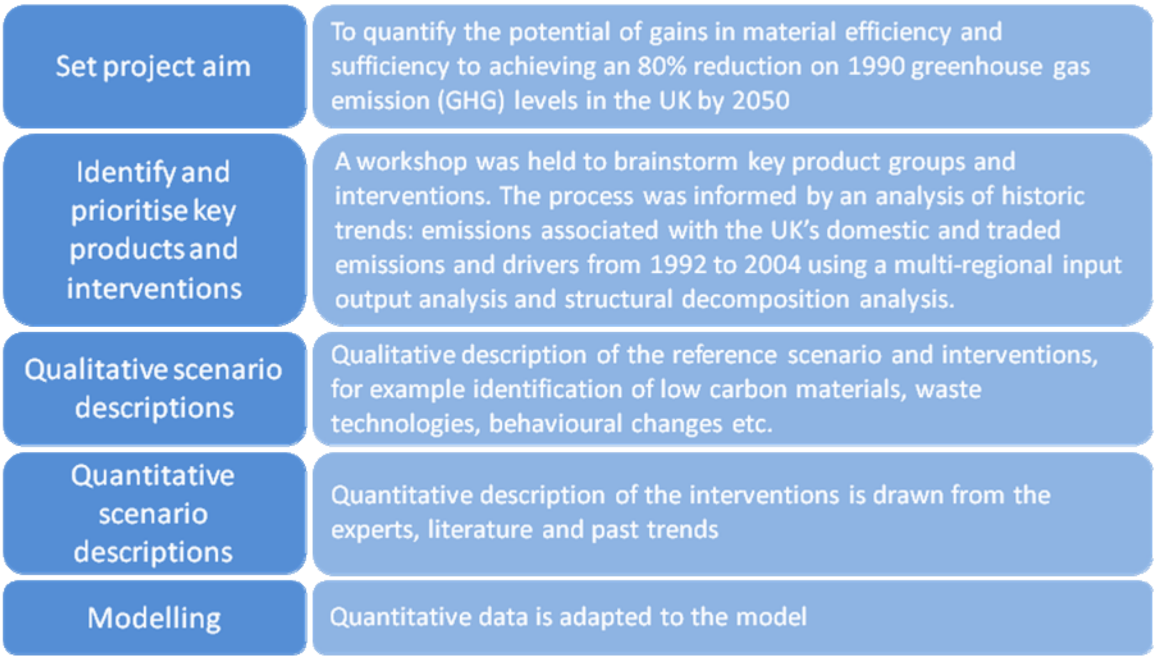
[24] *Wiedmann, T., Wood, R., Lenzen, M., Minx, J., Guan, D. and Barrett, J. (2008)* Development of an embedded carbon emissions indicator*, report to the UK Department for Environment, Food and Rural Affairs by the Stockholm Environment Institute at the University of York and Centre for Integrated Sustainability Analysis at the University of Sydney, Defra, London, UK.*

[25] *Wiedmann, T., Lenzen, M. and Wood, R. (2008)* Uncertainty Analysis of the UK-MRIO Model – Results from a Monte-Carlo Analysis of the UK Multi-Region Input-Output Model (Embedded Emissions Indicator)*; Report to the UK Department for Environment, Food and Rural Affairs by Stockholm Environment Institute at the University of York and Centre for Integrated Sustainability Analysis at the University of Sydney. Defra, London, UK*

[26] *Minx, J.C., Baiocchi, G., Wiedmann, T. and Barrett, J. (2009)* Understanding Changes in CO2 Emissions from Consumption 1992-2004: A Structural Decomposition Analysis*, Report to the UK Department for Environment, Food and Rural Affairs by Stockholm Environment Institute at the University of York and the University of Durham, DEFRA, London, UK, not yet published.*

[27] *Nansia, K, Kagawa, S., Suh, S., Inaba, R. and Moriguchi, Y. (2007) Simple Indicator to Identify the Environmental Soundness of Growth of Consumption and Technology: "Eco-velocity of Consumption",* Environmental Science and Technology, *41, 1465-1472.*

Figure 3: Scenario framework




This led to a list of potential resource efficiency and sufficiency strategies that affected both the demand for products and the efficiency of supply. The list of strategies was then aggregated together to form 13 key strategies relating to either supply side or demand side measures. Supply side measures tackle the efficiency of production or production structure in the UK. Demand side measures address the level of household consumption or composition of household products. The term "sufficiency" has been included to describe some scenarios that would reduce consumption in particular product groups. Within these cases the re-bound effect has been explored, with scenarios presented with and without the rebound effect, acknowledging the considerable uncertainty surrounding it.

Based on the expert's judgement - sector experts from AEA, environmental economists from SEI and resource experts from WRAP - these strategies were categorised into three different levels of intervention to indicate actions that would achieve 'quick wins' compared to those which would need to overcome significant investment, infrastructural, technological or cultural barriers. This constructed three scenarios made up of a range of supply and demand strategies to provide insight into the effectiveness of a combination of measures, reflecting the workings of the economy as a whole, not just an adjustment of supply or demand side. Most of the strategies are included in all three of the scenarios, differing in their level of intervention. In addition to this, a Reference Scenario has been developed that acts as a benchmark by which to compare the other scenarios.

In summary, the scenarios are:

- Reference scenario – The scenario takes into account both historical trends, and uses econometric modelling to suggest a plausible future for the UK economy.
- Quick Win scenario – Identifies what can be achieved in the short term across all the resource efficiency strategies using the time period of 2010 to 2020 (continuing to 2050 at the same level). These strategies are defined as being relatively easy to implement as they do not require additional costs or major technology and or cultural shifts.
- Best Practice scenario – Identifies the possible reductions in GHG emission that could be achieved if the best currently available technologies and consumption behaviours were adopted across all appropriate sectors and households by 2050.
- Beyond Best Practice scenario – The scenario provides an insight into the maximum potential of the resource efficiency strategies assuming that all major barriers could be removed so that the strategies could recognise their full potential. The scenario timeline is until 2050.

## 2.4 Scenario modelling

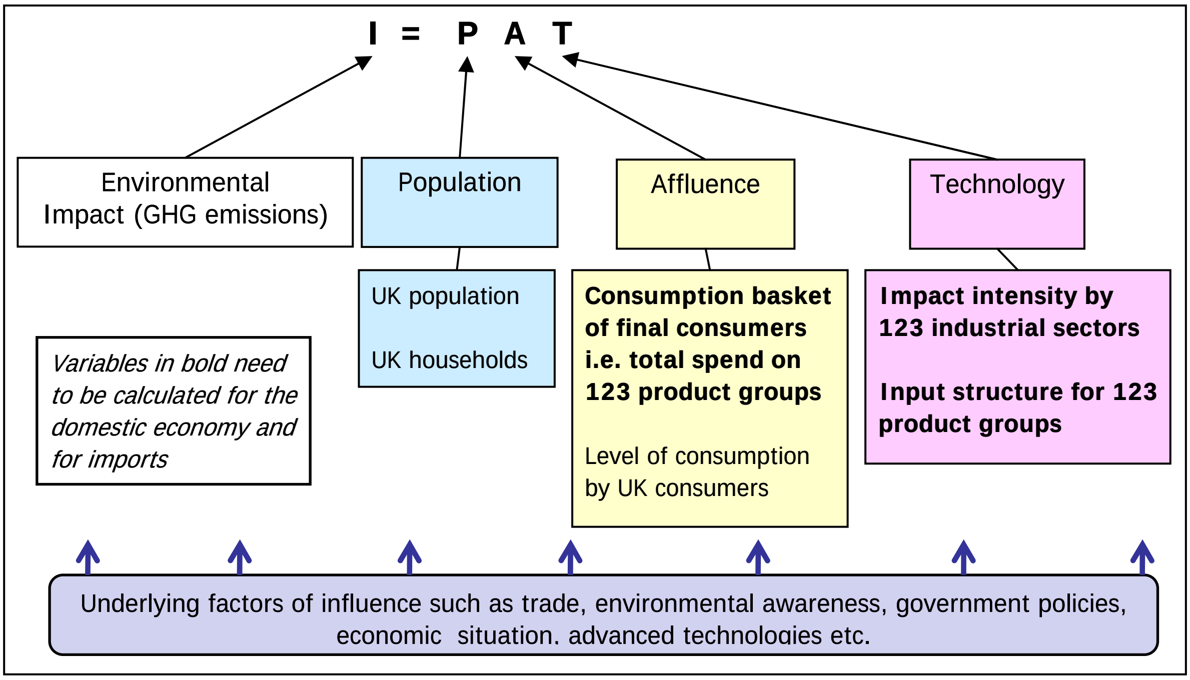
Building on the historic analysis and current projections of the different driving forces affecting UK consumer emissions, we construct four scenarios illustrating potential levels of UK emissions up to 2050. All the scenarios are built on the variables produced as part of the structural decomposition analysis (SDA). The SDA provides an understanding of the drivers behind UK GHG emissions and it is these variables that are projected. This makes it possible to understand the contribution of different resource efficiency and sufficiency strategies in changing technology (supply side changes that change the production structure or inputs into the economy) and consumption (demand for products and composition of household products) (see Figure 4 for more details).

The SDA variables expand on the basic I=PAT equation developed by Ehrlich and Holdren in the early 1970s (a similar approach has been adopted by Agnolucci et al., 2009[28] and Guan et al., 2008[22]). From a resource efficiency perspective, the equation implies that:

> *to stabilise or reduce environmental impact (I) as population (P) and affluence (A) increase, technology (T) needs to be dematerialised* (Nansai et al., 2007) [27]

These factors have a direct impact on emissions but can be influenced by a range of underlying factors (drivers) such as patterns of trade, education, environmental awareness, advanced technologies and government policies.

Figure 4: SDA variables




We first constructed the reference scenario on the future development of the UK economy using Experian's Economic model to 2050. The environmental component, GHG intensities of production, were extrapolated from SEI's environmentally-extended MRIO model. Direct emissions from households were taken from the MARKAL energy model. We adopted 2004 as the baseline as this is the latest year that all the data is available for[29]. The economy is classified into 123 product groups aligned with UK National Accounts.

Each strategy was modelled separately, and where relevant at different levels of intervention, by altering any one of the four components of affluence and technology listed in Figure 4. These were then combined into three resource efficiency and sufficiency scenarios representing Quick Wins, Best Practice and Beyond Best Practice.

[28] *Agnolucci, P., Ekins, P., Iacopini, G., Anderson, K., Bows, A., Mander, S. and Shackley, S. (2009) Different scenarios for achieving radical reduction in carbon emissions: a decomposition analysis,* Ecological Economics, *68, 1652-1666.*

[29] *With the exception of direct household transport and energy data from the MARKAL model where we have a baseline year of 2005*

## 3.0 Evaluating the past – The historical evidence

This section provides an insight into historical trends in UK GHG emissions from 1992 to 2004, the time period for which this information is available. The evidence presented in this section is the first provided for the UK which describes in detail the complete global supply chain greenhouse gas impacts of all goods and services consumed in the UK over the past two decades.

The value of understanding historic trends is that understanding what happened in the past can help identify likely future trends and products that are most in need of further resource efficiency measures in the future. Historic trends give us an understanding of progress made in the UK, whether the UK is on a sustainable trajectory, and what savings are needed to ensure its targets are met.

Two models are used to understand changes in GHG emissions in the UK between 1992 and 2004.

1. *Territorial emission model*: this is the sectoral emissions released by UK industries for the production of goods and services consumed domestically and overseas and emissions released directly by households (i.e. includes emissions embodied in UK exports). The overall emissions correspond to those reported in the UK Environmental Accounts and form the basis of the majority of climate change agreements. Included in our model is the emissions associated with international aviation and shipping, the two sectors excluded from the Kyoto Protocol.
2. *Consumer emission model*: this is the emissions released globally to satisfy all final demands in the UK, including direct household emissions. Therefore the model considers all the GHG emissions generated in other countries from the production of goods and services imported to the UK and excludes emissions from the production of UK exports.

Both can be analysed in terms of direct emission contributions and direct and indirect emissions. The total of the two add up to the same, however, how they are assigned to sectors differs. Direct emissions are those emitted on-site at the industry and direct and indirect are emissions associated with life cycle of goods and services produced by industrial sectors i.e. we assign all supply chain emissions to the sector of final use. The first will be referred to as a direct perspective, the second as a product perspective.

Most of the analysis relates to sectoral emissions, not including direct household emissions. The source of direct household emissions are energy use in the home and private transport and are therefore not of relevance to this report, the focus of which is material use. Where total emissions are presented, these are given with and without direct household emissions. It is however important to stress that when we present the scenario results later, direct household emissions are included in the reference scenario ensuring that this represents total UK emissions.

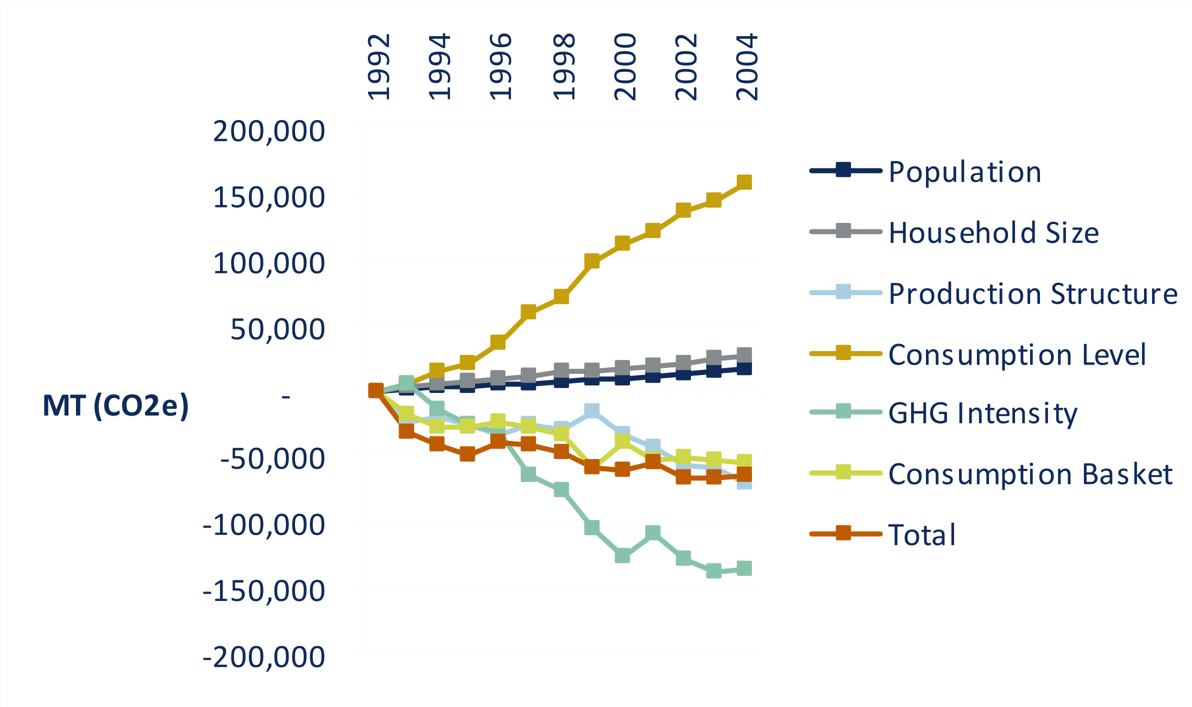
The results that follow are presented in a question and answer format to highlight key issues that inform our understanding of UK emissions.

### 3.1 What are the main drivers behind changes in UK territorial emissions between 1992 and 2004?

Figure 5 summarises UK territorial GHG emission trends for UK industrial sectors (i.e. excluding direct emissions from households). Between 1992 and 2004 total territorial sectoral emissions reduced by 66 Mt$CO_2$e (8% reduction). Including emissions released directly from households this saving reduces to 54 Mt (a 7% reduction) due to an 8% rise to household emissions. Improvements in resource efficiency (a combined measure of the GHG intensity of production and the production structure of industry) have offset increased emissions from escalating consumer spending, population growth and declining household occupancies. The increase in consumer spending would have increased territorial emissions by 157 Mt if all other factors had remained at 1992 levels. Similarly a rising population and declining household size would have added 41 Mt combined to the emissions account.

These emission gains were offset by emission reductions achieved through improved resource efficiency measures and greener consumer purchasing. Through changes in the production structure of the UK economy and industries on average improving their intensity of production savings of 70 and 137 Mt respectively were achieved. Also changing consumer patterns towards products with lower climate change impacts contributed to cumulative reductions in GHG emissions of 56 Mt. As highlighted, this lead to overall reduction in GHG emissions of 7%.

Figure 5: Drivers behind changes in cumulative sectoral territorial GHG emissions in the UK, 1992 to 2004, Mt $CO_2e$




| |
|---|
| ***Key Message: the evidence shows that resource efficiency has contributed to reducing UK territorial emissions. However, the full potential of resource efficiency gains have not being realised due to increased consumer levels.*** |

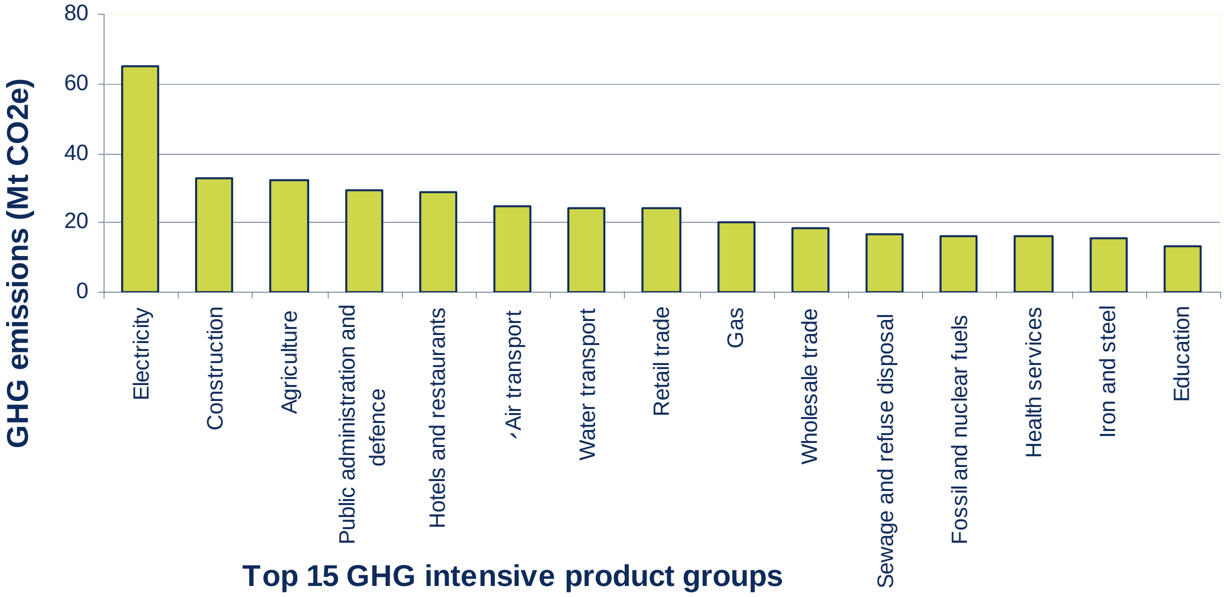
## 3.2 What are the big-hitting sectors in the UK and which sectors are making the most substantial progress?

The territorial model disaggregates the UK economy into 123 sectors. We can distinguish between a direct and product perspective. The former looks at those emissions produced on-site by each industry, the latter the supply chain impacts in providing the product by each sector. Here we focus on the latter, whereby we account for emissions along the domestic supply chain of goods and services produced in the UK. Two thirds of UK territorial GHG emissions from industry come from 15 product groups (Figure 6). The top 15 'big hitters' have remained fairly consistent throughout the time series (1992 to 2004), with gas being the only sector to significantly rise into the top 15 emitters mainly due to the "dash for gas". Transport sectors, particularly aviation and shipping, are among the fastest growing sectors causing their emissions to double in between 1992 and 2004, the majority of which can be associated with international aviation and shipping (Agnolucci et al., 2008[28]). These are the two sectors currently outside the Kyoto Protocol.

Many people assume most services have little to no environmental impact associated with them, yet half of the top 15 emitting sectors are service sectors. Services act as an interface between primary and secondary industry and household consumers. In a study of American households, Suh (2006)[30] found that households consume 86% primary sector outputs and 44% secondary sector outputs indirectly, mainly through services. 85% of emissions associated with services are induced from the supply chain providing products in order to deliver the service. Therefore when taking a product or lifecycle perspective compared to a direct approach the impacts of services are increased.

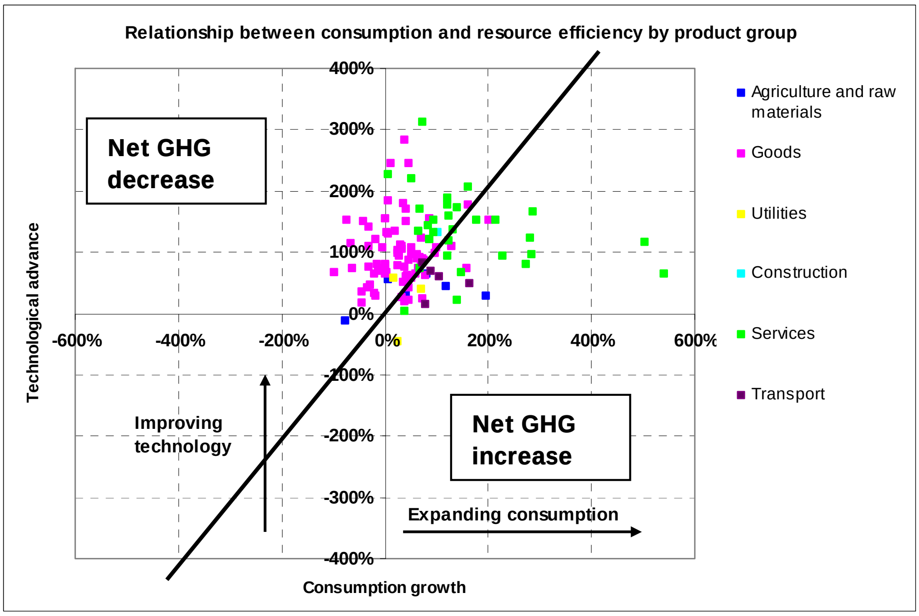
[30] *Suh, S. (2006) Are services better for climate change?* Environmental Science and Technology, *40 (21), 6555-6560.*

Figure 6: The 'big-hitters': the highest 15 impacting sectors




We apply the eco-velocity indicator developed by Nansai et al. (2007)[27] to examine the two most fundamental drivers of GHG emissions over time: rates of consumption growth and the GHG intensity of production, indicating whether industry efficiency measures are sufficient to mitigate GHG emissions. Figure 6 gives a visual representation comparing the rate of consumption growth with industry efficiency improvements (quantified in terms of embodied GHG missions per £million product) for 123 domestic product groups for the time period 1992 to 2004, identifying which product groups are "eco-speeding". Eco-speeding is the term used to identify products where growing levels of consumption are offsetting emissions saved through production efficiency improvements. The term Eco in "eco-speeding" however does seem misleading as it is these products that are causing emission increases and therefore we simply now refer to these groups as those that increase emissions. In Figure 7, product groups falling below the solid line on the scatter plot lead to net emissions increases, and those above the line result in emission reductions.

Figure 7: The relationship between changing consumption and resource efficiency by domestic product group, 1992 to 2004



Of the 123 product groups produced in the UK, 72% of the sectors sit above the solid line and are moving towards a "climate friendly development path", albeit some very slowly. Efficiency improvements in providing these products are outpacing their growth in consumption leading to a reduction in emissions. Approximately a quarter of UK manufacturing industries are improving in efficiency whilst the demand for them is reducing. Efficiency gains in the rest are largely greater than the increase in consumption. On the other hand, in half of UK service sectors rising consumption demands are offsetting the gains in efficiency, indicating the growing importance of service sectors in driving emissions. The continual shift to services represents an economy-wide trend, with services representing 63% of the economy in 1992 and 69% in 2004, yet GHG emissions from services dropped from 37% of total UK emissions in 1992 to 36% in 2004. This is due to services having generally lower emission intensities (i.e. produce less GHG emissions per pound spent on a product).

Table 1 shows the number of products whose emissions are increasing by high level product groups, with the bracketed figure representing the total number of products within each high level product group. Of the 28% of product groups where consumption growth is outpacing technological advance leading to rising emissions, 41% are services, 29% goods, 12% agriculture and raw material products, 12% transport related and 6% utilities (Table 1).

Table 1: Product groups eco-velocity[31]

| | *Total number eco-speeding[32] in 2004* | *Percentage eco-speeding in 2004* | *Percentage contribution to sectoral territorial emissions in 2004* |
|---|---|---|---|
| Agriculture and raw materials | 4 (7) | 57 | 8 |
| Goods | 10 (77) | 13 | 24 |
| Utilities | 2 (3) | 67 | 15 |
| Transport | 4 (5) | 80 | 11 |
| Services | 14 (30) | 47 | 36 |
| Construction | 0(1) | 0 | 6 |
| ***Total*** | ***34 (123)*** | ***28*** | ***100*** |

***Key Message: Services are significant contributors to UK emissions, with emission growth occurring in half the service sectors in the UK. Just over a tenth of domestic manufacturing sectors contributed increasing emissions in 2004.***

## 3.3 What progress have material producing sectors made in the UK?

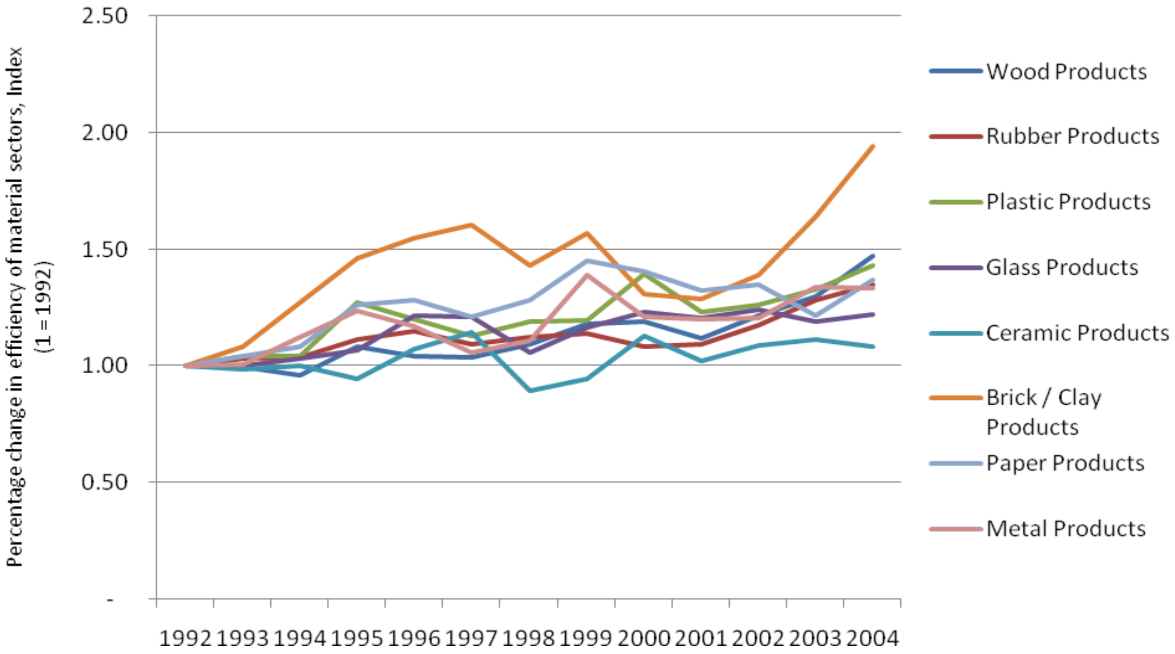
The results from the territorial model show that from a product perspective all material sectors in the UK have achieved efficiency improvements. Figure 8 focuses on changes in the GHG intensities of production of key material-product sectors. These sectors contributed £10 billion to UK GDP and accounted for just under seven million tonnes of UK GHG territorial emissions in 2004.

Emissions from domestic material production are declining in all these sectors with the exception of wood products. All these products have made improvements in resource efficiency in comparison to the baseline year of 1992. However, there is considerable variation between product groups. Bricks have been delivered to the economy almost twice as efficiently in 2004 than 1992, an annual improvement of 7%. At the other end of the spectrum, ceramic products have improved resource efficiency by a rate of 0.7% a year over the same time period.

*[31] The rate of consumption growth in consumption compared with the rate of efficiency improvements between 1992 and 2004*

*[32] Consumption growth is greater than efficiency improvements*

Figure 8: Resource Efficiency Improvements in UK Material Sectors




***Key Message: All material sectors have become more efficient***

## 3.4 What is the contribution of individual greenhouse gases to overall emissions?

The reduction in territorial GHG emissions has been driven by reductions in non-$CO_2$ gases. Methane emissions have halved, nitrous oxide have reduced nearly a third and fluorinated gases just over a quarter, whilst territorial carbon dioxide emissions, which make up approximately 75% of GHG emissions, have increased by 2% since 1992

Table 2 shows changes in emissions for the individual GHGs).

Table 2: Changes in GHG emissions by sector, 1992 to 2004, Mt $CO_2e$

| | $CO_2$ | $CH_4$ | $N_2O$ | Fgases | Total GHGs |
|---|---|---|---|---|---|
| Agriculture and raw materials | 3 | -1 | 1 | 0 | 3 |
| Manufacturing | -15 | -8 | -15 | -7 | -45 |
| Energy and water utilities | -3 | -7 | 0 | 0 | -10 |
| Transport | 21 | 0 | 0 | 0 | 21 |
| Services | 0 | -31 | -5 | 1 | -35 |
| Construction | -2 | -1 | -1 | 0 | -4 |
| Direct households | 7 | -1 | 3 | 3 | 12 |
| **Total** | **10** | **-49** | **-17** | **-3** | **-59** |

The transport sector is responsible for the majority of $CO_2$ emission growth (mainly shipping and aviation). Previous research by the Stockholm Environment Institute (Minx et al., 2009[26]) identified two major factors behind trends preventing sectoral $CO_2$ emissions in the UK mounting: changes in the fuel mix, notably the dash for gas, and the UK's continual trend towards a service economy. Both drove territorial $CO_2$ emissions down in the early 1990s. In order to reduce $CO_2$ emissions, resource efficiency measures would need to outpace growing consumption levels, yet fuel use in the UK continued to rise by more than 10% between 1992 and 2004 and the positive carbon effects of switching from predominantly coal to gas have begun to level off since the late 1990s.

Considerable reductions in methane emissions have been achieved in the waste treatment sector as a result of reduced emissions from landfill[33]. These savings are included in the service sector in

Table 2 (waste disposal services). Nitrous oxide and fluorinated greenhouse gas emission reductions have largely been achieved through reductions in the manufacturing of chemicals.

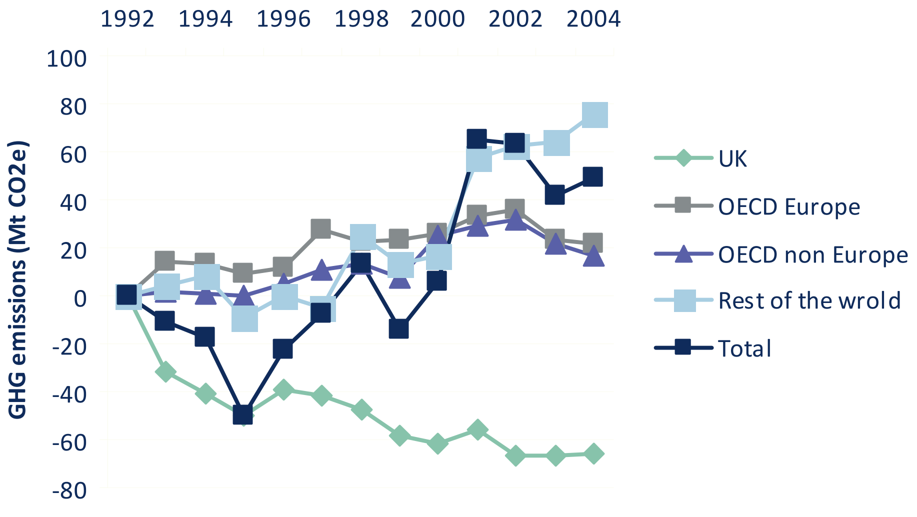
***Key Message: Whilst changes in the waste treatment sector and chemical manufacturing have driven substantial reductions in non-$CO_2$ GHG's, growth in the transport sectors primarily caused absolute $CO_2$ emissions to rise.***

## 3.5 What are the global drivers behind changes in UK consumer emissions between 1992 and 2004?

Our consumer model aggregates the world into four production regions separating the UK from OECD-Europe, non-Europe OECD and the rest of the world. When taking a consumption perspective, in 2004 UK emissions are 29% higher than territorial emissions. Figure 9 shows the trends in regional sectoral GHG contributions to products purchased by UK consumers. Between 1992 and 2004 total sectoral consumer emissions (i.e. excluding direct emissions from households) increased by 49 $MtCO_2e$ (7% increase). Including direct household emissions this increase rises to 61 Mt.

The chart reveals that only the UK's emission contribution to changes in consumer emissions decreased between 1992 and 2004. Overall 65 Mt less $CO_2e$ emissions were released in the UK economy for the production of goods and services consumed in the UK than in 1992. However, growing additional GHG emissions were required in all the three other regions to support UK consumption. The proportion of emissions embedded in imports from UK consumer emissions was 22% in 2004, rising from 10% in 1992. Whilst the increase in emissions from the production of imports in the more industrialised regions was moderate (22 Mt in OECD-Europe and 17 Mt in OECD non-Europe), GHG emissions from imports from non-OECD grew much more rapidly by 76 Mt between 1992 and 2004.

Figure 9: Changes in UK sectoral consumer GHG emissions by emitting region, 1992 to 2004, Mt $CO_2e$




There are well documented concerns in the literature about this trend, which are not acknowledged using a purely territorial-based accounting mechanism. Approximately 25% of industrialised countries emissions are embedded in imports and are associated with the problem of carbon leakage (Peters and Hertwich, 2006[13]). Recent research has shown that around 5 Gt of $CO_2$ is embedded in the international trade of goods and services,

[33] *http://www.defra.gov.uk/environment/statistics/globatmos/gagccukem.htm*

most of which flows from non-Annex I to Annex I countries (Peters, 2008[14]), presenting a serious problem to Kyoto signatories in the developing world and undermining the effectiveness of environmental policies (Peters and Hertwich, 2008[34]). Under the Kyoto Protocol, non-Annex countries have no binding target and additional import requirements from UK consumption will therefore drive global emissions upwards.

***Key Message: Emission reductions from UK production affect only a small proportion of emissions driven by UK consumption, therefore, taking a global resource efficiency perspective, there is a need to reduce production impacts elsewhere.***

## 3.6 What are the main structural drivers behind changes in UK consumer emissions between 1992 and 2004?

Table 3 shows the drivers behind rising sectoral consumer emissions: those released globally for products consumed in the UK. There are clearly two competing trends: improved intensities of production (cis), globally has saved 241 Mt $CO_2e$. These savings have been offset by rising consumer demand (yl) in the UK, leading to an additional 274 Mt $CO_2e$. Other drivers have a relatively smaller impact: 14 Mt were saved from greening global supply chains (L), and a further 42 Mt were saved by changing UK consumption patterns (ys). These were offset by 44 Mt and 29 Mt increases in emissions driven by reducing household occupancy levels (hhsize) and population growth (pop). As a consequence overall emissions from UK consumption have increased by almost 50 Mt $CO_2e$.

Table 3: Drivers behind UK consumer emissions, 1992 to 2004, Mt (cis – production intensities, L – production structure, yl – consumption levels, ys – consumption basket, hhsize – household size, pop – population)

| | *cis* | *L* | *yl* | *ys* | *hhsize* | *pop* | *Total* |
|---|---|---|---|---|---|---|---|
| UK | -137 | -70 | 157 | -56 | *25* | 16 | -65 |
| OECD Europe | -25 | 2 | 33 | 3 | *5* | 3 | 22 |
| OECD non Europe | -3 | -7 | 27 | -6 | *4* | 3 | 17 |
| Rest of the world | -76 | 61 | 57 | 18 | *9* | 6 | 76 |
| *Total* | -241 | -14 | 274 | -42 | *44* | 29 | 49 |

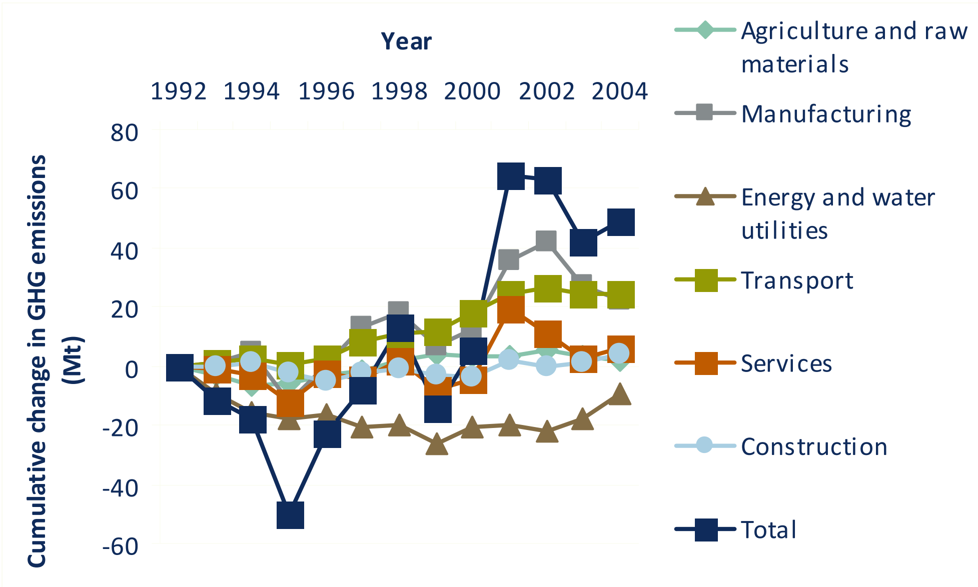
***Key Message: Resource efficiency measures alone are not currently enough to create a low carbon economy, and focus must be paid to escalating consumption patterns.***

## 3.7 What are the big-hitting products consumed in the UK and what products are on a climate friendly development path?

Figure 10 shows that travel is responsible for the fastest growing emissions, partly through less efficient production outside of the UK and partly through increasing demand. This is closely followed by manufactured goods adding 22 Mt to the consumer account mainly from rising demand. The purchasing of services, construction and agricultural products adds 6, 4 and 2 Mt to UK consumer emissions. The only products leading to reduced emissions is energy and water utilities (-10 Mt). Whilst energy demand is rising, the intensity of energy production is becoming less carbon intensive (due in large part to the dash for gas).

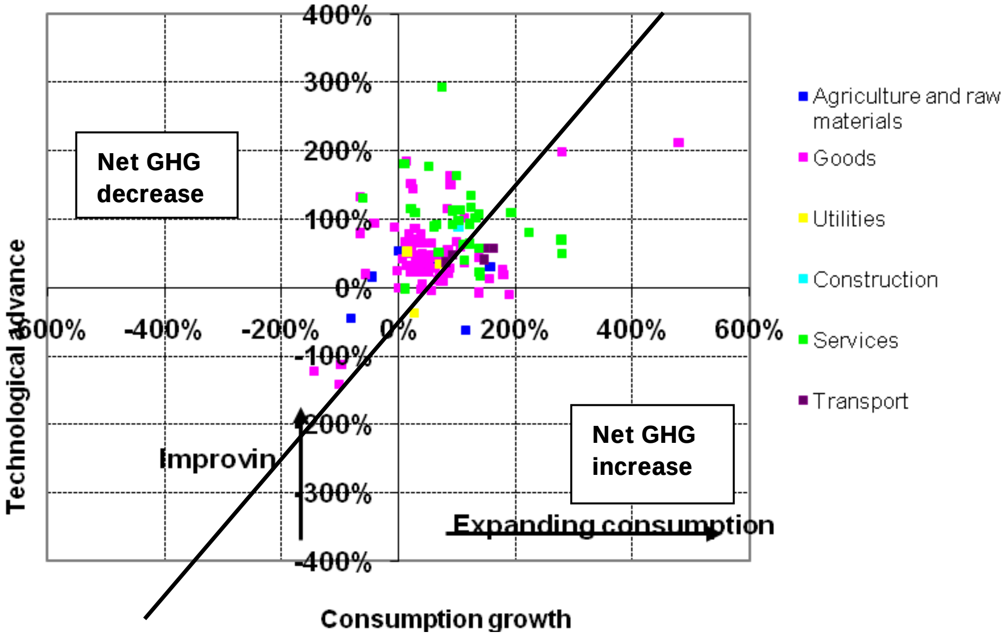
*[34] Peters, G.P. and Hertwich, E.G. (2008) CO2 embodied in international trade with implications for global climate policy, Environmental Science and Technology, 42 (5), 1401-1407.*

Figure 10: Changes in consumer emissions by sector, 1992 to 2004, Mt $CO_2e$




Applying the eco-velocity indicator to consumer emissions, only 41% of the 123 product groups produced globally for UK consumption are moving towards a climate friendly development path (the products above the solid line in Figure 11), compared to 72% when taking a territorial perspective. The most notable difference relates to manufactured goods, with only 13% of domestically produced goods causing emissions gains compared with 55% from global supply chains. Demand for 25% of domestically produced manufactured goods is slowing, yet demand for only 11% of goods produced globally for UK consumption is slowing.

Figure 11: The relationship between changing consumption and resource efficiency by product group consumed in the UK (i.e. includes production efficiencies of imported products), 1992 to 2004




Of the 57% of product groups whose emissions are increasing, 60% are goods, 24% are services, 7% transport related, 4% agriculture and raw material products, 3% utilities, and 1% is construction.

***Key Message: Growing demand in the UK is outpacing efficiency gains, with 60% of goods and services moving along an unsustainable trajectory, causing consumer emissions to continue to rise.***

## 3.8 Key conclusions

The results presented give vital insight into understanding how UK emissions have changed in the last two decades and why. There are some key messages to extract from the evidence that should be considered when looking at opportunities to reduce future UK emissions.

- Service sectors are substantial procurers of manufactured goods and are therefore deeply connected to primary and secondary industries. From a lifecycle perspective, service sectors are significant contributors to UK emissions. To simply take the view that services have little or no impact associated with them ignores this relationship and would fail to reduce emissions to the required level. From a territorial perspective, the importance of service sectors is growing, re-emphasising the need to focus on strategies aimed at service sectors in the UK.

- Comparing a territorial and consumer approach, the evidence strongly supports the claim that the UK is increasingly relying on carbon intensive manufacturing overseas to meet growing consumer demand.

- Growth in the transport sector is the main driver behind rising $CO_2$ emissions. All other GHGs have been considerably reduced in the same time period.

- At present, resource efficiency and sufficiency measures are not delivering the reductions required to reduce absolute emissions, and attention must be made to UK consumer patterns.

- Accounting for the impact of imports reveals that the UK's contribution to climate change is increasing. There is little evidence to suggest that this situation will change in the short term.

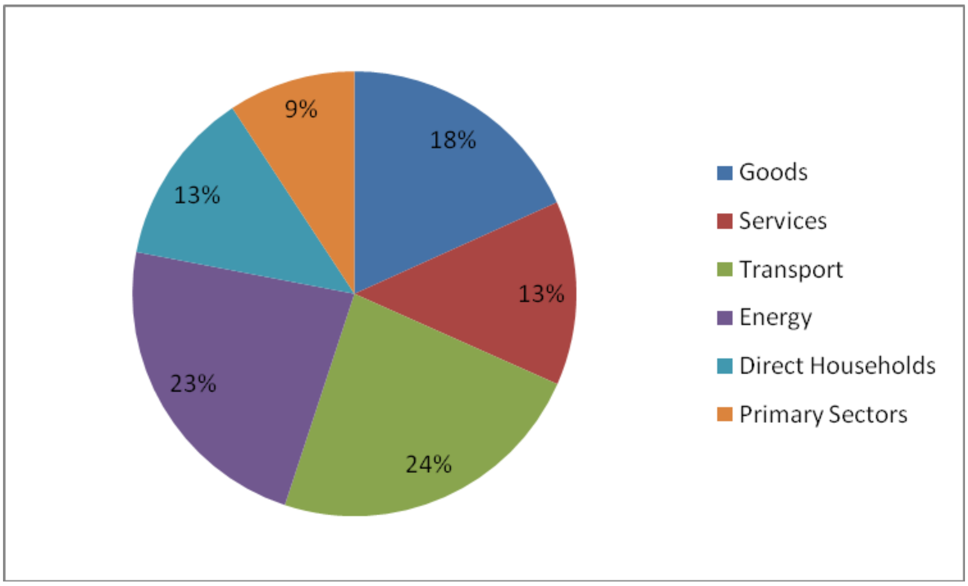
## 4.0 Resource efficiency and sufficiency strategies for the UK

The historical evidence presented provides a strong signal that the UK cannot currently rely solely on resource efficiency measures to meet climate change targets, and that influencing the demand side is therefore another prerequisite. This view is shared by the Deputy Executive for UNEP:

> *It will only be by a combination of resource efficiency and resource sufficiency measures that the ultimate goal of sustainable consumption and production patterns can be achieved* (Cropper, 2009[3])

This report provides evidence for the potential of a number of resource efficiency strategies for mitigating UK consumer GHG emissions, covering both the supply of and demand for products. Supply relates to production within the UK and demand relates to UK consumption of all products, whether produced domestically or abroad. Focus remains within the material good and service sectors which are projected to account for 32% of UK consumer emissions in 2050 (see Figure 12).

Figure 12: Estimated percentage share of UK consumer emissions in 2050




Seven strategies covering resource efficient supply and six resource efficient demand-side strategies were analysed. These strategies were developed as part of the participatory workshop approach that was adopted to inform the scenarios. These are not the only existing options, but are seen as promising GHG abatement options for the UK and the majority have featured somewhat on the sustainable development agenda.

These strategies are explored both individually and collectively to give an indication of which stand alone strategies are most promising and also what the overall contribution resource efficiency and sufficiency can achieve to meeting climate change targets. There is some overlap between the individual strategies, which has been overcome in the collective scenarios.

This section documents the data and assumptions underlying the scenario analysis. As noted previously, there is no right or wrong prediction of what will happen between now and 2050. Scenarios are not predictive, but provide evidence to answer *what if* questions. Due to the uncertainty attached to scenarios we aim to be as transparent as possible in documenting all our data and assumptions.

First we present the Reference scenario assumptions, which are based on future development of the UK economy for the period 2004 to 2050. This is followed by the individual strategies and modelling assumptions analysed in the report, drawing where possible on available evidence. The issue of the rebound effect is discussed and how it is dealt with in this project explained, followed by a description of the three collective scenarios constructed to explore resource efficiency and sufficiency pathways to achieve an 80% reduction in GHG emissions by 2050. Two important aspects are then discussed relating to cumulative emission accounting and the economics of meeting climate change targets.

## 4.1 Reference scenario

The purpose of the Reference scenario is to primarily act as a benchmark to assess the contribution of the strategies within the three scenarios. Therefore, it was important the reference scenario provided an understanding of:

- sectors that will be significant in the future and not just which sectors have been significant historically;
- changing efficiency and “efficiency pathways” of individual sectors;
- changing consumer preferences of products in the future;
- changing relationship between sectors in their delivery of products; and
- changing trade relations.

Instead of applying an existing “business as usual” scenario, it was felt appropriate to develop a new scenario that encompassed all these issues. It was concluded that an econometric approach[35] was required as there was not another modelling framework that could understand in as much detail the interactions between industries, consumers and product flows. As with any long-term scenario model, it is recognised that the ability to predict long in to the future is limited. In the shorter term however there is more certainty in the social, economic and political climate, which is reflected in changes in the model between 2010 and 2025. Therefore, in our opinion, the reference scenario outlines a coherent story of a potential future.

The starting point for the Reference scenario assumptions is a wide range of historical economic data that is collected at a highly disaggregated level and covers all the major economic indicators. The majority of this data comes from the Office of National Statistics (ONS). Data also comes from a number of other sources including the Labour Force Survey, the CBI’s survey of manufacturing industries, and the European Commission’s survey of consumer confidence.

After ensuring consistency between data from different sources and vintages, equations are constructed to represent the historical relationships between the several indicators. Each equation explains the performance of a particular indicator in terms of a number of other indicators. There is an equation for all the major indicators, at the national and regional level.

The overall forecasting approach is based on a methodology that combines long-term supply and demand influences with short-term demand side influences. In the short-to-medium term, the performance of the UK and regional economies is driven by demand side influences. However, supply potential is the long-term determinant of growth.

The model is used to produce an initial forecast which is evaluated by regional and sector experts in light of their detailed knowledge. Alterations are made for significant pieces of inward investment, or infrastructure development, or changes to European funding, in the form of ‘add factors’. A new forecast is then produced, which is again subject to rigorous inspection. Table 4 provides a summary of the key long-term assumptions relating to both supply and demand-side influences.

*[35] Econometric modelling applies quantitative or statistical methods to analyse economic relationships. This report projects the UK economy disaggregated into 123 sectors and four final demand categories and the interactions between them.*

Table 4: Summary of long-term Reference scenario assumptions

| | |
|---|---|
| ***Key long term supply influences*** | |
| Productivity growth | UK medium to long term GDP growth continues to grow at the 2.5 percent per year seen in the past two decades. |
| Employment growth | Employment growth is constrained by increasingly less favourable demographic conditions. The working age population is expected to remain relatively flat over the medium to long term due to lower birth rates and weaker international migration. |
| Employment rate | The proportion of working age people in employment is expected to continue to rise over the medium to long term, but the rate of increase slows as participation rates move towards their natural limit. |
| Industrial profile of future employment growth | Growing rates of employment is expected in leisure services, financial service, business services, communications, retail, hotels & catering, construction and health. By contrast, fewer jobs are expected in manufacturing, particularly in price sensitive activities, public administration and education. |
| Corporate investment | The outlook for corporate investment is more subdued than in the last business cycle. Pre-millennial IT spending played an important role in the previous boom, as did other technology investments. With a surge in public investment following the economic downturn, business investment recovered strongly in 2004 and is set to expand robustly in the next cycle, with inflation and interest rates remaining low and profitability solid. |
| ***Key long term demand influences*** | |
| Consumer spending | Household spending is expected to expand less rapidly than GDP over the next decade, expanding at 2% a year after 2020. A number of factors underpin this change. After years of carefree purchasing, households are saddled with unprecedented levels of debt relative to their incomes and it has become increasingly apparent that neglected savings are inadequate to safeguard incomes into old age. In the absence of shifts to working practices (such as later retirement), the only way to resolve this will be more cautious spending. In addition, housing and stock markets are expected to provide much less of a boost to personal wealth than in the previous decade, while real income growth is forecast to be dampened by slower employment and higher taxes. |
| Public sector spending | Public sector expenditure will contribute less on average to economic growth in the next 10 years. In the late 1990s the government's commitment to improve public services greatly boosted government demand in the last half-decade and is unlikely to end abruptly. However, the huge recent bail-out of the banking system by the government has brought government borrowing to unprecedented levels. It is clear that tax increases and government cutbacks will be put in place in the medium term, while other strains on public resources (an ageing population, pension underfunding) add to the pressures over the decade. |

Consumer expenditure was separated between domestically produced goods and services and imported products based on an extrapolation of this split in expenditure from historic National Accounts and trade data. The environmental component (the GHG intensities of production), were extrapolated from SEI's environmentally-extended MRIO model time series from 1992 to 2004. These are the GHG emissions released by each industry to produce a pound(£) of output. The GHG emissions are from Environmental Accounts and the sector output is from National Accounts.

All the other scenarios apply the assumptions outlined in the Reference scenario with an additional adjustment to a supply or demand side component when different resource strategies are taken into account. Changes are made to the GHG intensity and production structure of the UK economy, household and government consumption levels and consumption patterns.

## 4.2 Supply strategies

The concept of a sound material-cycle society has the objective of restraining the consumption of natural resources and reducing the environmental load (Hashimoto et al., 2008[36]; Moriguchi, 2007). This can be achieved through reducing the demand for a product (resource sufficiency) or through reducing the amount of material needed to produce a particular product. We deal with the latter in this section, generally referred to as eco-efficiency or efficient material management, where environmental and economic benefits are maximised while economic and environmental costs are minimised (Hekkert et al., 2002[37]; Five Winds International, 2001[38]; Amini et al., 2007[39]; Yagi and Halada, 2001[40]). Examples in industry include material substitution, material reduction, re-use and recycling of products and material efficient product design.

Any material that enters the economy will eventually emerge as waste. Producers need to think about impacts from the full lifecycle of a product, beyond the point of consumer purchase. More efficient production will reduce raw material requirements, save energy from raw material extraction and processing and reduce the amount of waste going into landfill. In order to reduce waste, material inputs need to be reduced. Opportunities to reduce the consumption of natural resources in the production process can be achieved through a variety of strategies. Figure 13: Resource efficient supply strategiesshows the supply strategies analysed in this study.

Whilst we do not provide the possible policy drivers of this development, eco-efficiency will be directly driven by production economics, technologies, the price of raw materials and influence from public policies.

Figure 13: Resource efficient supply strategies

| | |
|---|---|
| Lean Production | Reduced material inputs into production processes through the design of lighter and leaner products |
| Material Substitution | Substitution of highly carbon intensive materials for low carbon intensive materials |
| Waste Reduction | A reduction in waste at the production stage that directly leads to a reduction in material requirements |
| Re-direction of Landfill Materials | Diversion of waste from landfill to recycling |
| Dematerialisation of the service sectors | Improving the efficiency of product use in the service sector through extending the lifetime of products, reducing edible food waste and eradicating junk mail |
| Strategies for Sustainable Building | Improving efficiency by introducing modern methods of construction such as modular design and off-site construction |
| Efficient Use of Existing Infrastructure | Reduce material inputs into construction through replacing new build with retrofit |

[36] *Hashimoto, S., Matsui, S., Matsuno, Y., Nansai, K., Murakami, S. and Moriguchi, Y. (2008) What Factors Have Changed Japanese Resource Productivity? A Decomposition Analysis for 1995 – 2002,* Journal of Industrial Ecology, *12(5/6), 657.*

[37] *Hekkert, M., van den Reek, J., Worrell, E. and Turkenburg, W. (2002) The impact of material efficient end-use technologies on paper use and carbon emissions,* Resources, Conservation and Recycling, *36, 241-266.*

[38] *Five Winds International (2001)* Eco-efficiency and Materials*, report for International Council on Metals and the Environment, Ontario, Canada.*

[39] *Amini, S., Remmerswaal, J., Castro, M. and Reuter, M. (2007) Quantifying the quality loss and resource efficiency of recycling by means of exergy analysis,* Journal of Cleaner Production, *15, 907-913.*

[40] *Yagi, K. and Halada, K. (2001) Materials development for a sustainable society,* Materials and Design, *22, 143-146.*

### 4.2.1 Lean Production

A product can be produced more efficiently by reducing the amount of material in a product whilst maintaining its effectiveness. This strategy, also known as "right-weighting" is probably most widely discussed in relation to packaging. Some big supermarkets have committed to targets to reduce packaging waste in the immediate future.

Case studies by WRAP[41] show plastic drinks bottles that have been made 7.5% lighter; paper and paperboard products such as biscuit containers that have achieved an 11% reduction, plastic filming that has an 11 to 15% material saving; glass drinks bottles that have been made 34% lighter and together retail packaging that has achieved a 35% weight reduction.

Many products in the economy beyond packaging have the potential to be made lighter using less material input. Yagi (2001)[40] provides a summary of achievements in high strength steel, enabling large structures such as building foundations, vehices and long span bridges to be made using less steel. This requires thought to different materials and there properties, and the appropriate selection of materials. In this sense, the strategy can link closely with material substitution to high strength and long lasting materials.

In this report we have identified the goods which can be produced lighter, mainly packaging, structural metal products, buildings, electrical products, household goods such as furniture and transport vehicles. In total they are currently made using £53 billion of raw materials. These raw materials include wood, pulp and paper, plastics and synthetic resins, rubber, glass, ceramics, cement, lime and plaster, iron and steel and non-ferrous metals.

To explore the potential of "right-weighting" across a wide range of products, we apply the same percentage reduction to all products, as there is not enough evidence to manipulate each individually. The following assumptions were employed under each scenario:

- Quick Win scenario – the material requirement to produce the same good is 15% less in 2020.
- Best Practice scenario – by 2050, the material requirement is reduced by 50%.
- Beyond Best Practice scenario – by 2050 the material requirement is reduced by 75% (i.e. goods are made 75% lighter).

### 4.2.2 Material Substitution

Using less carbon intensive materials can also reduce the environmental impact of products. This requires careful selection of materials in order to reduce the intensity of production by choosing a material with a low impact, which in the case of this report is reducing GHG emissions.

There are many determining factors behind the choice of a material in product design depending on the application of the product: for example whether the product provides packaging for food with a short shelf life or whether it is the foundations of a house with a long life span. As such different materials will be chosen for their properties for example durability, re-usability, recyclability, strength and so on.

Whilst other factors, like whether the material is from a renewable source, are important, we focus here on the GHG intensities of material production and hence the embodied emissions in the different materials. Measured in GHG emissions per unit tonne of output, in 2004 for example, the iron and steel industry was over eight times more GHG-intensive than the plastics sector.

Whilst we cannot determine in detail the ability for material substitution in all products, we know that there is potential for movement towards less carbon intensive materials. We have used the direct intensity of plastic production as a proxy to explore the possibilities for material substitution, as it has the lowest carbon intensity of all the raw material sectors. Using plastic as a proxy for a low carbon material, we reduce the intensity of other raw material sectors (metals, glass, wood, cement, lime and plaster) to that of plastic. We are not assuming these materials are replaced with plastic, but exploring the potential to reduce the intensity of different material sectors.

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[41] *http://www.wrap.org.uk/retail/*

We assume:

- Quick Win scenario - 10% of all materials are replaced with the lowest carbon-intensive material, by 2020.
- Best Practice scenario – this increases to 20% by 2030.
- Beyond best Practice scenario – further efforts are made to increase this to 40% replacement of higher with lower carbon intensive materials by 2050.

### *4.2.3 Waste Reduction*

The following two strategies relate to the physical waste produced by industries. Every year the UK consumes 680 Mt of material, of which approximately half ends up as waste (ONS, 2009). Of this waste 25% relates to industrial and commercial waste, which has a high embodied carbon impact associated with it (Environment Agency, 2006[42]).

Inevitably, waste will be a by-product of industrial activity. Adopting the waste hierarchy, priority should be given to eliminating the waste. We assume that 15% raw materials produced end up in the waste stream from industry. By matching supply with demand, industrial demand for raw materials can therefore be reduced by up to 15%. However, we acknowledge that some of this waste is unavoidable: we assume this to be 10%.

This strategy assumes the following reductions in material input by manufacturing sectors:

- Quick Win scenario - 15% of the raw materials from industry and commerce ending up in the waste stream are taken out of the economy by 2020.
- Best Practice scenario – this increases to 50% by 2050.
- Beyond Best Practice scenario – accounting for 10% unavoidable waste, there is no additional waste in the economy by 2050.

Our scenarios reduce the money spent on waste treatment and disposal by the equivalent amount.

### *4.2.4 Redirection of Landfill Materials*

If reducing material input is not an option, re-use and recycling is the next best alternative. 58% of the waste produced from industry, commerce, construction and households is re-used, recycled or recovered, leaving 42% going to landfill (Environment Agency, 2005[43]). Much of this waste will degrade, creating methane, a GHG 25 times more potent than $CO_2$. With landfill at the bottom of the waste hierarchy, policies to divert waste from landfill play a very important role within national waste policies. Whilst considerable reductions in methane emissions have been achieved in the waste treatment sector as a result of reduced emissions from landfill, further reductions are possible.

Inevitably, there will be some waste which cannot be recycled (we assume 10%), whereas the remaining 32% of waste to landfill can be recycled back into production, reducing sectoral material demand. This reduces the demand for refuse disposal, whilst increasing demand for recycling facilities. This strategy assumes the following reductions in material input by each manufacturing sector, consequently increasing recycling activities:

- Quick Win - 15% of the raw materials ending up in landfill from industrial and commercial waste are recycled and put back into production by 2020.
- Best Practice – this increases to 50% by 2050.
- Beyond Best Practice – accounting for 10% unavoidable waste, all waste destined for landfill is recycled by 2050.

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[42] *Environment Agency (2006) Commercial and Industrial Waste Survey 2002/3, from DEFRA http://www.defra.gov.uk/evidence/statistics/environment/waste/kf/wrkf11.htm.*

[43] *Environment Agency (2005) National Waste Production Survey 2002, from DEFRA http://www.defra.gov.uk/evidence/statistics/environment/waste/wrindustry.htm.*

### 4.2.5 Dematerialisation of the Service Sectors

Many people assume services have little to no environmental impact associated with them, yet when taking a lifecycle approach the impacts of services are increased. This accounts for not only the direct impacts produced on-site, for example the energy used to heat and power the building, but it also allocates indirect emissions associated with products purchased in order to provide the intended service. In an analysis of the U.S. economy, Suh (2006[30]) finds that the magnitude of life-cycle/ indirect emissions compared with direct emissions is on average 16 times greater for tertiary service industries.

The previous strategies have covered material use by manufacturing sectors, however, service sectors purchase over £75 billion of manufactured goods to provide services to households. Services act as an interface between primary and secondary industry and household consumers. The majority of emissions associated with services are induced from the supply chain (primary and secondary sector outputs) manufacturing products in order to provide the services. Therefore, a continual shift to a service economy would not necessarily lead to reduced GHG emissions as services are deeply rooted to primary and manufacturing outputs. If the demand for services is increased, the demand for manufactured products subsequently increases.

This scenario considers three components of service industries: food waste, product optimisation and junk mail.

Food waste in service sectors is particularly relevant to the hotel, restaurant and catering industries, which produce approximately three million tonnes of food waste alone, half that arising from UK households. The remaining half comes from retailers, food manufacturers, agriculture and commercial food waste (e.g. hospitals and schools etc.) (WRAP, 2009[44]) . We apply the evidence that half of food wasted by households is edible, to all UK service sectors. Assuming this, the scenarios are as follows:

- Quick Win scenario - service sectors halve their edible food waste by 2020.
- Best Practice scenario – service sectors do not throw out any edible food waste by 2050.
- Beyond Best Practice scenario – service sectors meet the best practice earlier by eliminating edible food waste by 2030.

This scenario also assumes that goods used by services are used for their full technical life span before entering the waste stream. Goods include carpets and rugs, clothes and uniforms, electrical appliances and equipment, office machinery and computers, furniture and recreational and sports goods. The longer the good is used, the more often it can deliver its service and the higher its resource productivity.

Research undertaken by Tim Cooper at Sheffield University documents the percentage of products that are thrown away while still working. In his paper in the Journal of Consumer Policy, it demonstrates that on average 33% of all products thrown away are still working (Cooper, 2004[45]). Instead of applying this figure to all the products listed above, the paper does give individual discard rates for products groups. Table 5 below provides these for the key product groups and the average annual saving for service sectors if products were used for their full life.

[44] *WRAP (2009)* Non-Household Food Waste *from http://www.wrap.org.uk/retail/food_waste/nonhousehold_food.html, accessed September 2009.*

[45] *Cooper, T. (2004) Inadequate life? Evidence of consumer attitudes to product obsolescence,* Journal of Consumer Policy, *27, 421-449.*

Table 5: Product discard rates and money saved by service sectors using products to their full technological lifespan

| *Product Group* | *Discard Rate (Disposed of while still working)* | *Monetary Saving if technological obsolescence is reached in all service sectors (£m)* |
|---|---|---|
| Carpets and rugs | 50% | 65 |
| Clothes and uniforms | 50% | 202 |
| Domestic appliances n.e.c | 33% | 174 |
| Office machinery and computers | 59% | 126 |
| Electrical equipment | 33% | 274 |
| Electronic components | 33% | 62 |
| Transmitters for TV, radio and phone | 33% | 1,400 |
| Receivers for TV and radio | 44% | 392 |
| **Total** | | **2,695** |

The scenario assumptions made are:

- Quick Win scenario – A third of discard rate is reduced for the different product groups by 2020.
- Best Practice scenario – From 2020 onwards, this trend continues and by 2050, 90% of goods reach their technological obsolescence.
- Beyond Best Practice scenario – The goals of the best practice scenario is achieved earlier, reaching 90% by 2030.

The third aspect of service provision relates to advertisements and commercial printing. Paper is wasted since it is used to deliver information about products that are of no interest to the receivers (Hekkert et al., 2002[37]). As a Quick Win strategy junk mail is eradicated by 2020, preventing 550,000 tonnes of paper use, amounting to 4.4 per cent of UK's annual consumption of paper and board.

### *4.2.6 Strategies for Sustainable Building*

Modern Methods of Construction (MMC) or off-site construction offer significant potential to minimise construction waste compared to traditional on-site construction. Several studies have found corresponding evidence that suggests modular homes can reduce waste by 70 to 90%, through better material management. Houses can be made using on average 10% less material tonnage (WRAP, 2007[46]; BRE, 2009[47]; Barrett and Wiedmann, 2004[48]).

The scenario assumptions made are:

- Quick Win scenario - 2% of the construction market is met by modular building design by 2020.
- Best Practice scenario - 5% of the construction market is met by modular building design by 2050.
- Beyond Best Practice scenario - 10% of the construction market is met by modular building design by 2050.

[46] *WRAP (2007)* Current Practices and Future Potential in Modern Methods of Construction, *http://www.wrap.org.uk/downloads/Modern_Methods_of_Construction_-_Summmary.eb890a56.3663.pdf.*

[47] *BRE (2009)* BeAware Supply Chain Resource Efficiency Sector Report, Modern Methods of Construction, *http://www.bre.co.uk/filelibrary/pdf/rpts/BeAware_MMC_Sector_Report_02Mar09.pdf.*

[48] *Barrett, J. and Wiedmann, T. (2004) A comparative carbon footprint analysis of on-sire construction and an off-site manufactured house, SEI and ISA[UK] research report 07-04.*

### *4.2.7 Efficient Use of Existing Infrastructure*

Of the 26 million homes in the UK, on average, 25,000 houses are demolished every year and there are currently 3.1% vacant (The Empty Homes Agency, 2009[49]). This scenario explores the option to meet rebuilds by retrofitting the existing stock, with the intention of reducing the input material required by the construction industry, one of the highest impacting sectors. This would involve 7% of homes.

Whilst *40%House* (Boardman et al., 2005[50]) look at increasing demolition rates in the UK as new builds are designed to be more energy efficient (reducing household energy demand), this scenario has a material focus and considers the indirect emissions embodied in the housing stock. It looks at reducing emissions using the existing housing stock.

We know the material requirement for the average new build in the UK is 117 tonnes (Wiedmann and Barrett, 2004[48]). Refurbishment takes out the material demand for the foundations (over 80% of the total material requirement), yet there are key aspects where maintenance is required, such as windows, doors, roof tiles and the interior. This gives us the new material requirement for retrofitting the existing housing stock. The scenario assumptions made are:

- Quick Win scenario - Retrofitting 20% of housing deemed for demolition and vacant properties offsets the need for rebuilding by 2020.
- Best Practice scenario - This continues to 50% by 2030.
- Beyond Best Practice scenario - By 2050, we assume that 90% of these properties are brought back into use, reducing the need for new builds.

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[49] *The Empty Homes Agency (2009) Empty Homes Statistics 2008 – Breakdown by Local Authority, http://www.emptyhomes.com/usefulinformation/stats/2008breakdown.htm*

[50] *Boardmand, B., Darby, S., Killip, G., Hinnells, M., Jardine, C., Palmer, J. and Sinden, G. (2005)* 40% House*, Environmental Change Institute, University of Oxford.*

### 4.2.8 *Summary of supply side strategies and assumptions*

| Resource Efficiency Strategy | Scenarios | | |
|---|---|---|---|
| | Quick Win | Best Practice | Beyond Best Practice |
| Lean Production | Material requirement to produce the same good is 15% less in 2020 | By 2050, the material requirement is reduced by 50% | By 2050 the material requirement is reduced by 75% |
| Material Substitution | 10% of carbon-intensive materials used to make goods are replaced with the least carbon-intensive material by 2020 | This increases to 20% by 2030 | Further efforts are made to reduce this to 40% by 2050 |
| Waste Reduction | 15% of the raw materials from industry and commerce ending up in the waste stream are taken out of the economy by 2020 | This increases to 50% by 2050 | Except for 10% unavoidable waste, there is no additional industrial and commercial waste in the economy by 2050 |
| Re-direction of Landfill Materials | 15% of the raw materials from industry and commerce ending up in landfill are recycled and put back into production by 2020 | This increases to 50% by 2050 | Accounting for 10% unavoidable waste, all waste destined for landfill is recycled by 2050 |
| Dematerialisation of the service sectors | A third of discard rate is reduced for the different product groups, edible food waste is halved and junk mail is eradicated by 2020 | By 2050, 90% of goods reach technological obsolescence and edible food waste is eliminated | The goals of the best practice scenario are achieved earlier, by 2030 |
| Strategies for Sustainable Building | 2% of the construction market is met by modular building design by 2020 | 5% of the construction market is met by modular building design by 2050 | 10% of the construction market is met by modular building design by 2050 |
| Efficient Use of Existing Infrastructure | Retrofitting 20% of housing deemed for demolition and vacant properties offsets the need for rebuilding by 2020 | This continues to 50% by 2030 | By 2050, we assume that 90% of these properties are brought back into use, reducing the need for new builds. |

## 4.3 Demand strategies

The historical evidence supports that we cannot rely on resource efficiency improvements to reduce emissions, but that we must pay attention to what and how much we consume. Sustainable consumption of materials can be driven by material efficiency and material sufficiency. Material efficiency achieves a given level of utility using less (material) input, whereas material sufficiency is doing without (Alcott, 2008[51]). As shown by Cooper (2005)[52], efficiency alone would lead to 'green growth', which is problematic if environmental gains from improved efficiency are offset by the rebound effect (discussed later in this section). Sufficient or reduced consumption is similarly challenging as it could lead to less production causing unemployment and recession.

The concept of a functional economy introduced by Stahel in the 1980s has the objective of 'creating the highest possible use value for the longest possible time while consuming as few material and energy resources as

[51] *Alcott, B. (2008) The sufficiency strategy: Would rich world frugality lower environmental impact?* Ecological Economics, *64, 770-786.*

[52] *Cooper, T. (2005) Slower consumption: reflections on product life spans and the "throwaway society",* Journal of industrial Ecology, *9 (1-2), 51-67.*

possible' (Stahel, 1986[53]). Under this concept are strategies aiming to slow the rate at which products are consumed by increasing their durability and providing careful maintenance. For example, by increasing the lifespan of a product, it provides a longer service and therefore its resource productivity increases. Households can use goods longer, businesses' can provide a service instead of selling a good therefore intensifying the use of products, or goods can be re-used through second-hand markets. Figure 14 shows the strategies explored in this report to reduce consumption of products by households and government.

If consumers use products longer, they can potentially save the money they would have used to replace the product. This introduces the rebound effect, whereby this money is spent on other goods or services which can offset the intended environmental gain. The rebound effect is discussed in more detail later in this section.

Figure 14: Resource efficient demand strategies

| | |
|---|---|
| Lifetime Optimisation | Ensuring that products are used by households for their full useful life |
| Shift from Goods to Services | Reduction in ownership or goods, delivered instead by the service sectors |
| Reducing Food Waste | Reduction in edible food waste within households |
| Dietary Changes | Reduction in animal-based food products through the introduction of more healthy diets |
| Restorative Economy | Extending the life of products by improving product durability |
| Public Sector Procurement Efficiency | Government lead the way in sustainable procurement |

### *4.3.1 Product Lifetime Optimisation*

This strategy explores different approaches to ensuring that a product is used for its full lifetime and does not enter the waste stream before this. Cooper (2004[45]) finds that psychological, technological and economic factors exert as much influence on life spans as technical reliability/ durability. In terms of psychological obsolescence, people may replace a product when they are no longer attracted or satisfied with a product due to, for example, peer pressure and fashion. A product may reach technological obsolescence when a newer, more advanced product is released onto the market, or a product may become economically obsolete when people attach little value to it, for example when a product becomes cheaper to replace than repair. Cooper's studies show that the extent to which products are thrown away due to technical failure is limited, and other factors are consequently more responsible. Therefore, in order for increased product life spans to be a successful strategy and have a positive environmental impact, consumer attitudes and behaviours need to be modified.

We have identified key household expenditure on material goods that have the possibility to be used longer, thus reducing their replacement rate: clothes, household appliances, glassware, tableware, household utensils, household tools and equipment, vehicles, telephone and telefax equipment, audio-visual, photo and information processing equipment and cultural and recreational durables. Of the total household spend in 2004 of £732 billion, £143 billion of expenditure was on these goods that could last longer.

Research undertaken by Tim Cooper at Sheffield University documents the percentage of products that are thrown away while still working. In his paper in the Journal of Consumer Policy, it demonstrates that on average

[53] *Stahel W. (1986) The Functional Economy: Cultural and Organisational Change, available from the Product Life Institute: http://www.product=life.org/publications.htm.*

33% of all products thrown away are still working (Cooper, 2004). Instead of applying this figure to all the products listed above, the paper does give individual discard rates for products groups. Table 6 provides these for the key product groups and the average annual savings households could make.

Table 6: Product discard rates and money saved by households using products to their full technological lifespan

| Product Group | Discard Rate (Disposed of while still working) | Monetary Saving if technological obsolescence is reached by all households (£m) |
|---|---|---|
| Clothing | 33% | 12,247 |
| Glassware, tableware & household utensils | 33% | 1,530 |
| Tools and equipment for house & garden | 21% | 980 |
| Purchase of vehicles | 33% | 12,801 |
| Telephone & telefax equipment | 44% | 378 |
| Audio-visual, photo & info. processing equipment | 49% | 10,692 |
| Other major durables for recreation & culture | 41% | 2,226 |
| Other recreational equipment etc. | 21% | 5,259 |
| Household appliances | 22% | 1,224 |
| **Total** | | **47,387** |

For each of the scenarios the assumption is adopted that extending the lifetime of the product reduces expenditure on these items. The rebound effect is dealt with in the next section, where we discus how to re-allocate money saved by households. The assumptions below provide an insight into the possibility of product optimisation in isolation from other interventions.

- Quick Win scenario – A third of discard rate is reduced for the different product groups by 2020.
- Best Practice scenario – From 2020 onwards, this trend continues and by 2050, 90% of reach their technological obsolescence.
- Beyond Best Practice scenario – The goals of the best practice scenario is achieved early, reaching 90% by 2030.

### *4.3.2 Goods to Services*

The UK is already experiencing a domestic shift from manufacturing goods to providing services. Both economic and environmental gains can be achieved through a service economy. For example, in the concept of a functional economy (the core idea being that products fulfil certain functions, such as a washing machine washing our laundry) the longer a product is used, the more often it can deliver its service and the higher its resource productivity. If products are seldom used, by sharing the product with a number of people (changing use patterns), the resource productivity of the product will be increased and the consumption of natural resources in the production stage reduced. For further discussion on product-service systems and their sustainability potential refer to Tukker and Tischner (2006)[54]. As the product maintenance become an internal expense and not the output of a company, profit can be maximised by minimising material goods.

We have identified key household expenditure categories on material goods that have the possibility to be provided instead through the delivery of services. Of the £732 billion total household spend in 2004, we have identified £148 billion of expenditure on material goods that could be shifted to services. This does not mean that this will or even could happen completely, due to numerous reasons related to the structure of the economy, value and cultural constraints and political direction. Therefore, in none of the scenarios have we assumed a complete shift of this expenditure but varying degrees of change.

[54] *Tukker, A. and Tischner, U. (2006) Product-services as a research field: past, present and future. Reflections from a decade of research,* Journal of Cleaner Production, *14, 1552-1556.*

There will be much more scope for providing services for items that are seldom used, for example ski equipment, where renting is already relatively common, compared with frequently used items such as washing machines (Hirschl et al., 2003[55]). This is not to say that modern service concepts should be confined to products of occasional use.

We assume a certain percentage transfer from household expenditure on goods to buying the equivalent service. This percentage will differ depending on the good and how often it is used by households.

- Quick Win scenario –
  - Clothing: "High End" hiring of clothes is maximised to account for 10% of the clothes market by 2020.
  - Glassware and Tableware - Maximises of hiring for special events accounted for 10% of the market by 2020.
  - Tools and Equipment for House and Garden - Initial short term shift in the market of 20% by 2020.
  - Purchase of Vehicles - Return to 1992 level of hiring as a proportion of total household expenditure. This would equate to 20% by 2020.
  - Telephone and Audi Equipment, Recreational Equipment and Newspapers and Books - A 10%shift in the market by 2020.

- Best Practice scenario –
  - Clothing – No Further Reduction.
  - Glassware and Tableware - After 2020 there is a shift in the hiring of glassware and tableware for general use representing an increase in the market to 15% by 2030, 20% by 2040 and 30% by 2050.
  - Tools and Equipment for House and Garden - After 2020 there is a more significant cultural shift that continues the uptake of hiring. This corresponds to a 30% shift by 2030, 50% by 2040 and 70% shift by 2050.
  - Purchase of Vehicles - After 2020 there is a more significant cultural shift that continues the uptake of hiring. This corresponds to a 30% shift by 2030, 40% by 2040 and 50% shift by 2050.
  - Telephone and Audi Equipment, Recreational Equipment and Newspapers and Books - After 2020 there is a more significant cultural shift that continues the uptake of hiring. This corresponds to a 20% shift by 2030, 30% by 2040 and 40% shift by 2050.

- Beyond Best Practice scenario –
  - Clothing – No Further Reduction.
  - Glassware and Tableware - From 2020 onwards there is a more substantial shift that ends up as 50% of all glassware and tableware delivered as a service by 2050 with incremental increases over time.
  - Tools and Equipment for House and Garden - From 2020 onwards there is a more substantial shift that ends up as 90% of all household tools are delivered as a service by 2050 with incremental increases over time. The remaining 10% are frequently used items such as a screwdriver.
  - Purchase of Vehicles - From 2020 onwards there is a more substantial shift that ends up as 90% of all household vehicles are delivered as a service by 2050 with incremental increases over time.
  - Telephone and Audi Equipment, Recreational Equipment and Newspapers and Books - From 2020 onwards there is a more substantial shift that ends up as 60% of all household audio visual appliances are delivered as a service by 2050 with incremental increases over time.

[55] *Hirschl, B., Konrad, W. and Scholl, G. (2003) Noew concepts in product use for sustainable consumption,* Journal of Cleaner Production, *11, 873-881.*

### 4.3.3 Reducing Food Waste

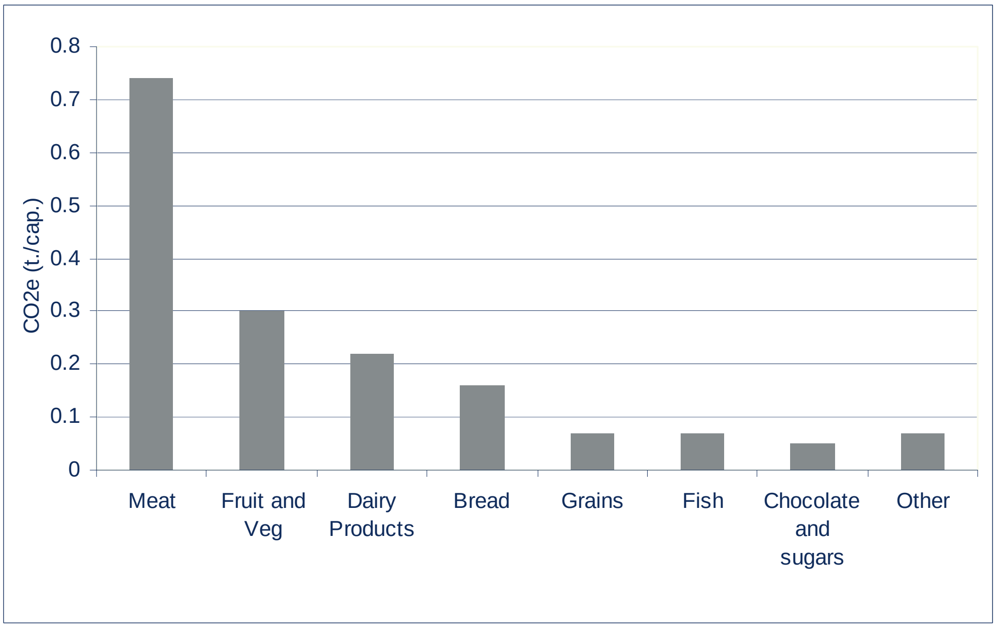
WRAP estimate that half of food thrown away by UK households is edible. When food ends up in landfill sites it biodegrades causing methane emissions. The key assumption of this scenario is that the householder will buy the right amount of food without the need to waste any. This is achieved through a reduction of expenditure on food. In the UK in 2004, nearly £66 billion was spent by the household on food, of which £10 billion pounds was spent on edible food which was subsequently wasted. The scenario assumptions are:

- Quick Win scenario - households half their edible food waste by 2020.
- Best Practice scenario – households do not throw out any edible food waste by 2050.
- Beyond Best Practice scenario – households meet the best practice earlier by eliminating edible food waste by 2030.

### 4.3.4 Dietary Changes

Food contributes around 2 tonnes per person to our UK footprint total of nearly 17 tonnes per capita (12% of the total). In an attempt to focus in on the key issues related to food, the analysis in Figure 15 gives an insight into the GHG emissions of food consumed by households.

Figure 15: GHG emissions of food purchased by UK households




Even without accounting for induced climate change impacts through deforestation and other major land-use change, meat and dairy products are of particular relevance in the climate change context due to their particularly high GHG intensity. Even though meat and dairy account for less than a quarter of the weekly average food intake in the UK, they generate nearly 60 percent of the food related GHG emissions.

Amongst the main animals we eat, ruminants (mainly cows) are the largest source of methane emissions per unit of feed intake. 50 percent of the carbon footprint associated with ruminant meat consumption in the UK is the belches by the animals on the farm. The most recent IPCC report highlights the difficulties of reducing these GHG emissions from livestock farming (Smith et al., 2007[56]). Much of the reduction will therefore need to come from the consumption side through changes in our diet. In the short-term considerable GHG savings can be realised by promoting healthy eating, which includes a lower meat diet.

The UK diet is currently too high in meat, dairy, high-fat and sugary foods and too low in fruit and vegetable intake. On average, everyone in the UK consumes 3,424 calories a day, 15 percent of which is from meat

*56 Smith, P., B. Metz, O. R. Davidson, P. R. Bosch, R. Dave and L. A. Meyer (2007)* Agriculture. Climate Change 2007: Mitigatuib, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge.*

products. The UK Department of Health recommend an average calorie intake of 1,940 calories per day for women and 2,550 calories per day for men. This suggests that there is the potential to reduce meat consumption, by far the most intensive component of the average UK diet. Not only would this be good for the climate, but for the well-being of people in the UK. With the treatment of dietary related illnesses costing the NHS yearly two billion pounds these are strong incentives for the government to actively promote healthy eating throughout the country.

This scenario indicates the emission savings from reducing meat and dairy consumption. It does not assume this is replaced with other food, as the figures above suggest this maintains a healthier diet. Therefore, the scenario assumptions are:

- Quick Win scenario - households reduce their meat and dairy consumption by a quarter by 2020.
- Best Practice scenario – households half their meat and dairy consumption by 2050.
- Beyond Best Practice scenario – households achieve a 75% reduction in meat and dairy consumption by 2050.

### *4.3.5 Restorative Economy*

This scenario relates to the durability of products and focuses on extending the lifespan of goods. It goes beyond the lifetime optimisation strategy to both increase the durability of goods and ensure people use them for their full life before replacing them. Cooper (2005)[52] puts forward a good argument for extending the lifetime of products through his concept of slower consumption:

> *Slowing the rate at which products are consumed (literally, "used up") by increasing their intrinsic durability and providing careful maintenance.*

Increasing product lifespan's, whether through greater durability or better maintenance, can provide for both efficiency and sufficiency. Materials will be used more productively and throughout will be slowed. Meanwhile, a shift to more highly skilled, craft-based production methods and increased repair and maintenance work will provide more employment opportunities to offset the reduced demand for new products.

Goods include clothes, household appliances, glassware, tableware, household utensils and equipment, vehicles, communication products, photo and information processing equipment and cultural and recreational durables. The scenario assumptions are:

- Quick Win scenario - households reduce expenditure on selected goods by 10% by 2020.
- Best Practice scenario – following on from the Quick Win scenario, an incremental reduction in expenditure in selected product groups to 30% by 2050.
- Beyond Best Practice scenario – Best Practice is increased to 40%.

### *4.3.6 Public Sector Resource Efficiency*

It is primarily the role of government to lead the way in exercising sustainable procurement. The 'Buy Sustainable – Quick wins'[57] act as a benchmark for sustainable procurement and form the foundations of this scenario. We assume the government adopt strict procurement standards for those material-related products set out in the Quick Wins, including office equipment, white goods, paper and office furniture.

There are a range of strategies that can achieve reduced impact of these goods, for example extended product lifetimes and buying a service instead of a product. We do not specify how these are achieved, but instead set a target for government as a leader of sustainable procurement. Our scenarios therefore assume:

- Quick Win scenario – the public sector reduces the impact of the goods they purchase by 5% per year by 2020.
- Best Practice scenario – by 2050, 90% the impact of government procured goods will have 90% less the impact.
- Beyond Best Practice scenario – the best practice scenario is achieved by 2030.

[57] *http://www.defra.gov.uk/sustainable/government/what/priority/consumption production/quickWins/index.htm*

### 4.3.7 Summary of supply side strategies and assumptions

| Resource Efficiency Strategy | Scenarios | | |
|---|---|---|---|
| | Quick Win | Best Practice | Beyond Best Practice |
| Lifetime Optimisation | The discard rate for different product groups is reduced by a third by 2020 | From 2020 onwards, this trend continues and by 2050, 90% of reach their technological obsolescence | The goals of the best practice scenario is achieved earlier, reaching 90% by 2030 |
| Goods to Services | A shift in the market to service provision, varies for selected goods of between five and 20 percent | A shift in the market to service provision, varies for selected goods of between 30 and 70 percent | A shift in the market to service provision, varies for selected goods of between 50 and 90 percent |
| Reducing Food Waste | Household halve edible food waste between 2010 and 2020 | From 2020 onwards, continue this trend to achieve a 100% reduction by 2050 in edible food waste | Achieve best practice goal set out in best practice scenario by 2030 |
| Dietary Changes | Meat and dairy consumption is reduced by 25% by 2020 | From 2020 onwards, continue this trend to achieve a 50% reduction by 2050 | From 2020 onwards there is a more substantial shift that ends up as 75% by 2050 |
| Restorative Economy | 10% reduction in expenditure on selected products by 2020 | Following on from the Quick Win scenario, an incremental reduction in expenditure in selected product groups to 30% by 2050 | This increases to 75% |
| Public Sector Procurement Efficiency | The public sector reduces the impact of the goods they purchase by 5% per year by 2020 | By 2050, 90% the impact of government procured goods will have 90% less the impact | The best practice scenario is achieved by 2030 |

## 4.4 Rebound effect

In many of the strategies related to changing final demand there has been a reduction in expenditure by households within specific product groups. For example, if households are going to replace products at a slower rate, as outlined in the lifetime optimisation strategy, the expenditure will reduce on these products. However, this does mean that households will not spend this money at all; they will simply spend it on other goods or services. In turn these products will have an impact and this is known as the rebound effect.

Whilst in the past the rebound effect has been referred to mainly in energy economics, its significance is now acknowledged in ecological economics, where resource use can be substituted for energy use. Attempts have been made to bring together research on the rebound effect (Sorrell, 2007[7]; Sorrell and Dimitropoulos, 2008[58]; Hertwich, 2005[59]; Greening et al., 2000[60]; Binswanger, 2001[61]), but the evidence base is methodologically

[58] *Sorrell, S. and Dimitropoulos, J. (2008) The rebound effect: macroeconomic definitions, limitations and extensions,* Ecological Economics, *65, 636-649.*

[59] *Hertwich, E. (2005) Consumption and the rebound effect,* Journal of Industrial Ecology, *9(1-2), 187-200.*

[60] *Greening, L.A., Greene, D.L. and Difiglio, C. (2000) Energy-efficiency and consumption – the rebound effect – a survey,* Energy Policy, *28, 389-401.*

diverse and studies focus mainly on transportation activities and household heating, which are not the focus of this report.

There is recognition that the rebound effect can be significant, yet its magnitude and importance are disputed. Some studies indicate that the rebound effect could be greater than 50 percent and even lead to increased consumption in the long run (Sorrell, 2007[7]). In this analysis, uncertainty exists in the allocation of the saved money by households. If products are produced to a better quality the price of these products may rise, meaning householders won't save any money. Alternatively if the right fiscal policies are put in place this could prevent additional money being spent on high impact products. Householders may adopt greener purchasing habits or alternatively take an additional holiday abroad. What is emphasised is that policy-makers can no longer neglect the rebound effect, as this will overestimate the contribution resource efficiency can make to reducing carbon emissions.

Previous research has assigned the saved money proportionally to the households existing expenditure profile (for example Takase et al., 2005[62]). This means that they will buy a little more of everything that they currently purchase. Historic trends show that households are proportionally increasing expenditure on services and so in this analysis it was decided to allocate the money to a range of service sectors to set give an insight into the possible impact of the rebound effect. Of course there is uncertainty attached to this, however, it highlights the associated issues and potential consequences of not accounting for the rebound effect.

Four demand side strategies were identified as having the potential to save households money on selected product groups: Lifetime Optimisation, Reducing Food Waste, Dietary Changes and the Restorative Economy. In the results section these are presented without the rebound effect to show the full potential the strategy could achieve if policies were in place to prevent adverse impacts of the rebound effect. Following the results we present a comparison of the results with and without the rebound effect.

## 4.5 Collective scenarios

To provide a collective understanding of the contribution of resource efficiency against UK consumer emissions to 2050, the strategies were combined into three scenarios. The scenarios were constructed from the range of supply and demand strategies to provide insight into the effectiveness of a combination of measures, reflecting the workings of the economy as a whole, not just an adjustment to supply or demand.

The three scenarios represent different levels of strategy intervention to show the potential of quick wins compared with ambitious interventions beyond what may seem feasible today. In summary, the three alternative scenarios are:

- Quick Win scenario– Identifies what can be achieved in the short term across all the resource efficiency strategies using the time period of 2010 to 2020. These strategies are defined as being relatively easy to implement as they do not require additional costs or major technology and or cultural shifts.
- Best Practice scenario – Identifies the possible reductions in GHG emission that could be achieved if current technologies and consumption behaviour was adopted across all appropriate sectors and households by 2050.
- Beyond Best Practice scenario– The scenario provides an insight into the maximum potential of the resource efficiency strategies believing that barriers could be removed to recognise their full potential. The scenario timeline is until 2050.

It is simply not possible to add up the benefits of each individual strategy to get an idea of what will be achieved by 2050 as some strategies are overlapping which would introduce double counting. The strategies are combined to exclude any overlap.

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[61] *Binswanger, M. (2001) Technological progress and sustainable development: what about the rebound effect?* Ecological Economics*, 36, 119-132.*

[62] *Takase, K., Kondo, Y. and Washizu, A. (2005) An analysis of sustainable consumption by the waste input-output model,* Journal of Industrial Ecology, *9 (1-2), 201-219.*

## 4.6 Cumulative emissions

In terms of stabilising atmospheric GHG emissions between now and 2050, it is vital that the UK constrains the total quantity of GHG emissions by 80% and not the level of emissions by 2050. Emissions levels ignore the importance of cumulative emissions on GHG stabilisation levels (Bows et al, 2006[63]). Long-term targets neglect the scientific evidence supporting the need for immediate cuts due to the importance of cumulative emissions in the atmosphere (Anderson et al., 2008[64]). Delaying action on stabilisation of GHG emissions in line with a 2 degree threshold will lead to both an increased risk of the very harmful impacts if climate change and higher mitigation costs (Stern, 2006[65]).

Therefore, to achieve the deep cuts in GHG emissions required, the environmental and economic advantages of immediate action have to be stressed. Quick wins will make savings now that will reduce cumulative emissions considerably up to 2050, whereas delaying action will only increase future values of emissions decline.

When presenting results of the contribution of resource efficiency strategies against UK emissions, we therefore present cumulative emissions. When looking at the direction of emissions from different sectors, emission levels are the most appropriate measure.

## 4.7 Economics of meeting targets

The release of the Stern Review has prompted a general acceptance that the UK needs to act now to limit the cost of climate change. There is common consensus that if we act now the cost of climate change will be within 1% of GDP a year, yet not acting will increase this cost considerably. Stern (2006)[66] estimates this damage could cost the global economy up to 20% and more a year. These are strong signals for immediate action.

The McKinsey Model estimates the prospective annual cost per tonne of avoided GHG emissions of different abatement technologies and strategies (Enkvist et al., 2007[67]). A strong message to take from this model, also used by Stern, is that 70% of possible abatements will come at no additional cost and are feasible with current technologies. This is particularly important as it infers that the Quick Wins described in this report can potentially boost the economy in the shorter term.

Several studies have shown that effective material management can be a cost efficient way to reduce emissions (Hekkert et al., 2002[37]). In this analysis we make adjustments to the interactions between material, good and service sectors and final demand in the UK economy, essentially reducing material flows throughout the economy. For example, in the strategy Lean Production, the same goods are produced using less material inputs. The expenditure of goods sectors on material sectors is reduced in the model. Another example is the waste reduction strategy, where industrial and commercial sectors reduce their waste.  We assume this reduces their material inputs by reducing expenditure on material sectors in the model. The model allocates the saved money as profit (i.e. to value added) to the goods sectors. This assumes there is no additional increase in the number of products being produced, but rather an increase in the profit of those sectors becoming more efficient. It is uncertain how this money will be spent, and we have not been able to incorporate the cost of investment in new technologies, which is of particular relevance to the Beyond Best Practice scenario. Further analysis is needed to explore this. Consequently, the material sectors will experience a decline in output due to reduced demand. From this perspective there is a shift in the distribution of money in the economy, yet overall output of the economy remains constant.

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[63] *Bows, A., Mander, S., Starkey, R., Bleda, M. and Anderson, K. (2006)* Living within a Carbon Budget. *Report Commissioned by Friends of the Earth and the Cooperative Bank, Tyndall Centre: Tyndall Centre, Manchester.*

[64] *Anderson, K., Bows, A. and Mander, S. (2008) From long term targets to cumulative emissions pathways: Reframing UK climate policy, Energy Policy, 36, 3714 – 3722.*

[65] *Stern, N. (2006) Stern Review on the Economics of Climate Change, HM Treasury, Cambridge University Press, Cambridge.*

[66] *Stern, N. (2006)* Stern Review on the Economics of Climate Change. *Her Majesty's Treasury. Cambridge University Press, Cambridge.*

[67] *Enkvist, P., Naucler, T. and Rosander, J. (2007) A cost curve for greenhouse gas reduction.* The McKinsey Quarterly, *2007(1).*

Demand-side strategies are treated in a similar way. For example, in the strategy of Lifetime Optimisation, we assume that households reduce expenditure on certain product groups as they delay replacing these. Therefore, households save money as it is assumed the price for products remain the same. In the main analysis, we do not redistribute this money to other products. The reason for this is the uncertainty associated with reallocating this money. In section 4.4 we present the rebound effect which details this issue. We explore re-allocating the saved money to a range of service sectors based on historical evidence that shows an increasing proportion of a households budget is being spent on services.

For each of the strategies we can extract the savings made in terms of a percentage of UK GDP compared to the reference scenario, taking the assumptions described above. These are given in Table 7. The percentages represent the annual level of saving from GDP. For example, Lean Production saves 0.89% of GDP in 2020 compared to GDP in 2020 in the Reference scenario. If Best Practice is adopted, this will save 1.6% of GDP in 2050 compared to the 2050 reference. For the supply strategies, these are the savings for the sectors with improved efficiency. For the demand strategies, these are the savings by consumers. There is no saving from material substitution as this does not assume a reduction in material input, instead a substitution of materials.

Table 7: Percentage saving compared to the Reference GDP

| *Strategy* | *Quick Win (by 2020)* | *Best Practice (by 2050)* | *Beyond Best Practice (by 2050)* |
|---|---|---|---|
| Lean Production | 0.89 | 1.60 | 1.60 |
| Material Substitution | - | - | - |
| Waste Reduction | 0.09 | 0.25 | 0.43 |
| Waste Recycling | 0.03 | 0.08 | 0.16 |
| Dematerialisation of Service Sectors | 0.04 | 0.06 | 0.06 |
| Strategies for Sustainable Building | 0.06 | 0.12 | 0.26 |
| Efficient Use of Existing Infrastructure | 0.06 | 0.14 | 0.24 |
| Lifetime Optimisation | 0.30 | 0.70 | 0.92 |
| Goods to Services | 0.46 | 0.93 | 1.43 |
| Reducing Food Waste | 0.14 | 0.23 | 0.23 |
| Dietary Changes | 0.18 | 0.23 | 0.33 |
| Restorative Economy | 0.00 | 0.54 | 0.73 |
| Public Sector Procurement | 0.03 | 0.10 | 0.10 |

However, the economy will adjust to structural changes between industrial sectors and consumers, which is likely to be reflected in the changing price of products. Therefore, the above view may be too simplistic. As a result of declining output in material sectors, the cost for materials is likely to change. In the Lifetime Optimisation strategy, if products are designed to last longer, the cost to produce them would potentially increase. The use of better quality materials and more skilled design could raise costs for the producer, therefore increasing the cost to the consumer. However, the model used in the analysis is not able to reflect the change in prices as the economy adjusts to changes in demand for materials and products throughout the economy. Clearly, further research is required to understand price changes in relation to resource efficiency. However, our initial assessment does suggest that the changes have a small effect on overall GDP, at least for what is feasible with current technologies and infrastructures.

## 5.0 Results

This section firstly presents the results of the reference scenario and where we estimate GHG emissions to be in 2050. Following this, the emission savings by each individual strategy are provided and finally the collective scenario results are given to illustrate the overall potential of resource efficiency in meeting UK GHG emissions targets. The study primarily provides an analysis of UK consumer emissions. A consumption perspective does not allow us to ignore the emissions induced abroad through UK consumer demands, however, as the 80% reduction target relates to UK territorial emissions, we indicate territorial emission levels to see the contribution to long and short-term government climate change targets.

Where relevant, emissions are presented in either annual emission level changes or cumulative emissions. The first indicates direction of travel and is currently how policies measure emissions; the second shows the total concentration of GHG emissions building up in the atmosphere. The text and charts will specify clearly which measurement has been used.

### 5.1 Reference scenario

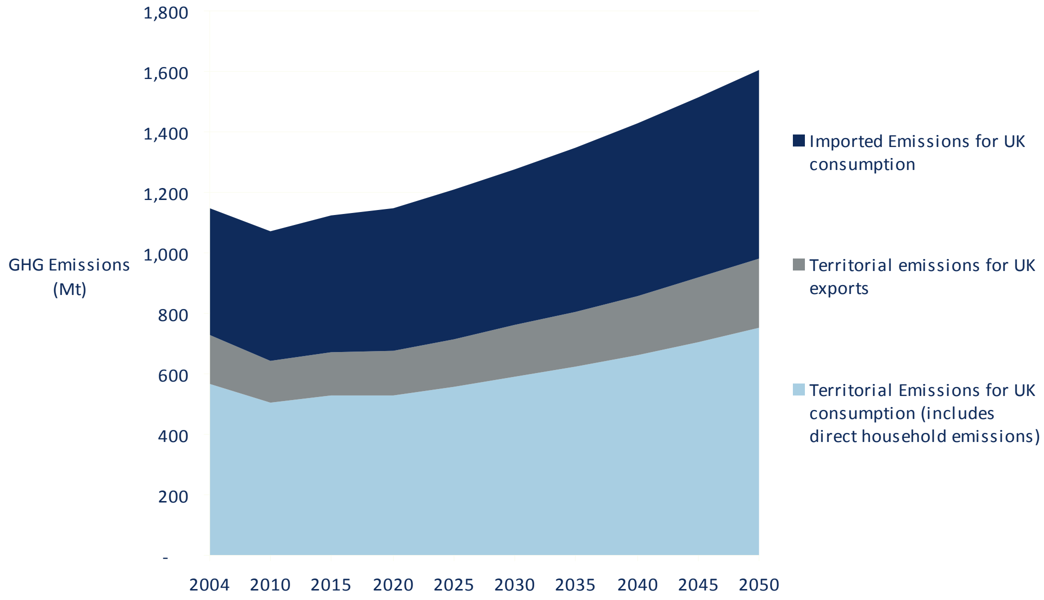
The Reference scenario gives an indication of the GHG emissions in the UK up to 2050 under a set of assumptions that are set out in section 4.1. The analysis has accounted for emissions released abroad for the production of goods consumed in the UK to give insight into the reduction of global GHG emissions by changing UK consumption patterns related to material use. By doing so, we have a full picture of the benefits of UK policy on resource efficiency. For example, if households reduced food waste and purchased less food then this would reduce GHG emissions in countries outside the UK that is imported to the UK.

As described in previous sections, the reference scenario has been constructed using Experian's econometric model to predict future economic growth, the changing structure of the economy and final consumption patterns, SEI's multi-regional input-output model to predict future technological efficiency of production and MARKAL, an energy systems model, to understand changing emissions in transport and housing sectors.

The key results of the reference scenario are shown in Figure 16 (see appendix 1a for results by product group). UK consumer emissions are the emissions released in the UK for UK consumption plus imported emissions for UK consumption. As noted, emissions from UK exports are shown to give an indication of projected UK territorial emissions: those released within the UK for both UK consumption and consumption abroad[68]. Figure 16 presents the level of projected emissions.

*[68] The main analysis focused on consumer emissions, however, to give an indication of export-related emissions, we have assumed exports from baseline year of 2004 have grown at the same rate as domestic products consumed in the UK. In the time series, the proportion of emissions from exports has remained relatively constant at approximately 29% of UK territorial emissions.*

Figure 16: Reference scenario GHG emission results




Our Reference scenario suggests an increase in UK consumer GHG emissions between 2004 and 2050 from 1 billion to 1.37 billion (an increase of 40%). This represents an annual growth rate in emissions of approximately 0.7% per year, which is very much in line with historical growth in UK consumer emissions that showed a 9% growth over the past 14 years. UK territorial emissions are estimated to grow by 34% from 0.73 billion to 0.98 billion tonnes of GHG emissions.

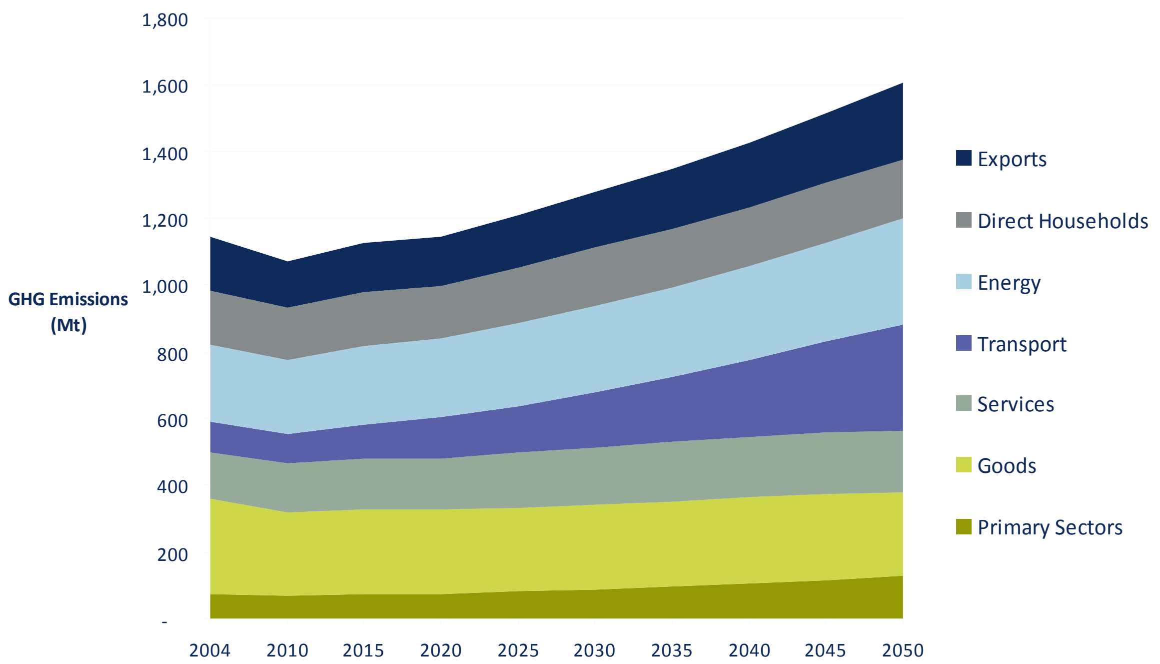
There is growth in both imported emissions and territorial emissions for UK consumption, although the growth is higher for imported emissions where a 50% growth between 2004 and 2050 can be seen, compared to 32% domestically.

It is clearly the hope of the UK Government that the target outlined in the Low Carbon Transition Plan is achieved, this being an 18% reduction by 2020 from 2005 territorial levels. Our reference scenario has not been able to take into account the full and successful implementation of this plan so therefore there is a possibility that the territorial emissions could be on a lower trajectory than suggested. The reference scenario has included the GHG emissions implications of the recession. Our suggestion is that territorial emissions will drop by 7% from 2004 levels to 2020. Post 2020, the reference scenario predicts economic recovery and a gradual climb in emissions as economic growth outpaces technological efficiency gains.

However, what is clear is that the most significant growth occurs in imported emissions. As these emissions are not officially the responsibility of the UK, there is no strategy in place to deal with them. It is hoped that a global deal at Copenhagen will lead to greater production efficiency globally and lower imported emissions for the UK.

In summary, the reference scenario highlights where UK consumer emissions could be if further action is not taken to tackle climate change. From a sector perspective, Figure 17 gives an indication of the changing GHG emissions of key high-level sectors.

Figure 17: Reference scenario GHG emission results by sector




There is considerable variation in the growth of different high level sectors (see Table 8). Transport demonstrates by far the highest growth of any sector with over a three-fold increase in the 46 year time period, primarily related to a growth in aviation. It is estimated that emissions from primary, energy and service sectors and household heating and car travel will have more moderate growth. A 33% growth in emissions from the service sector reflects a sector that is both improving in efficiency but failing to reduce emissions due to substantial growth. The only sector estimated to reduce emissions is the manufacturing of goods by 31 million tonnes (an 11% reduction).

Table 8: Percentage change of GHG emissions by sector, 2004 to 2050.

| *High level sector* | *Percentage change* |
|---|---|
| Primary sectors | 167 |
| Goods | 89 |
| Services | 133 |
| Transport | 333 |
| Energy | 138 |
| Direct households | 108 |
| Total | 140 |

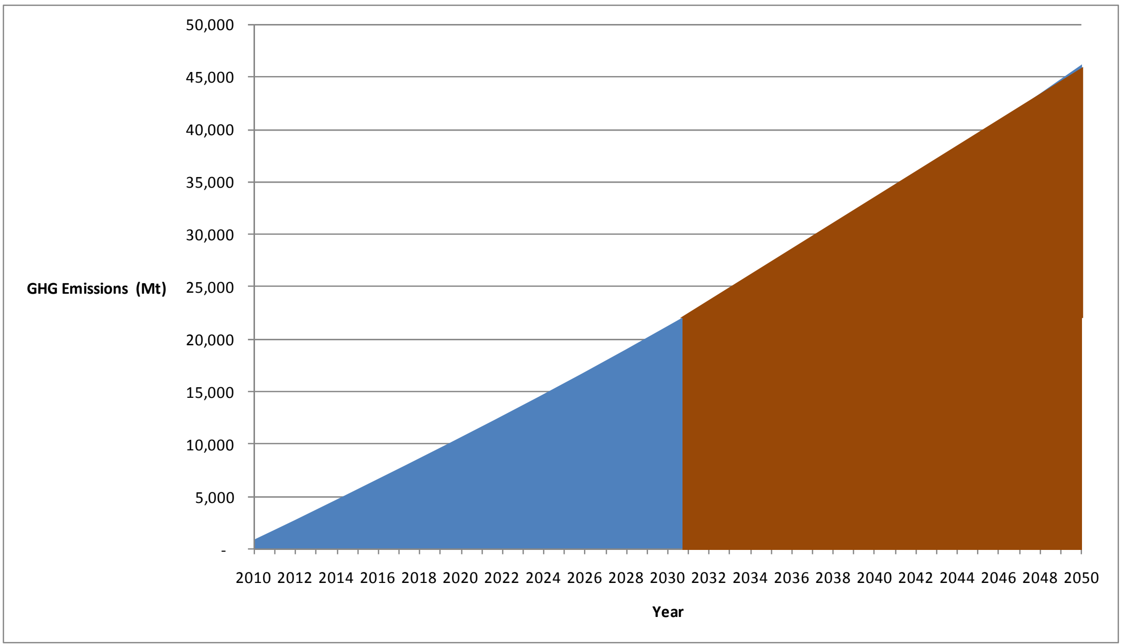
Due to the focus of material resource efficiency strategies, the scenarios have influenced only specific sectors relating to materials, goods and services (i.e. excluding energy and transport[69]). It is estimated that these sectors will account for 435 million tonnes and represent 32% of total emissions in 2050.

There is large variation in emissions among the goods and services sectors affected. For example, within the reference scenario emissions from government procurement, food and chemical sectors are expected to rise. Emissions from commercial services, machinery and electrical equipment remain stable, whilst material producing sectors are in decline.

[69] *including retail and wholesale trade*

Finally, Figure 18 shows cumulative UK consumer emissions for the time period 2010 to 2050 to indicate the total concentration of GHG emissions in the atmosphere induced by consumption in the UK. Assuming the UK needs to achieve an 80% reduction in consumer emissions, we can use this to derive the UK's carbon budget (the total GHG emissions the UK can release into the atmosphere each year until 2050). The blue triangle gives an indication as to when the UK will have used up its complete carbon budget from now until 2050 based on the reference scenario. If the UK takes no action to reduce emissions, the analysis estimates that any emissions released from UK consumption beyond 2031 are additional to the UK's carbon budget.

Figure 18: Reference scenario cumulative GHG emission results




## 5.2 Resource efficiency and sufficiency strategies

Results for the 13 individual strategies are now presented (see appendix 1b for strategy results by product group). The results presented are in cumulative emission savings to show the total estimated GHG emissions prevented from entering the atmosphere. In order to make a fair comparison, savings from exports are shown with the supply-side results. More efficient production in the UK will reduce emissions released into the atmosphere for the production of exports. When documenting demand-side strategy results, the savings are from the consumer account as these measures influence not only domestic but also imported emissions.

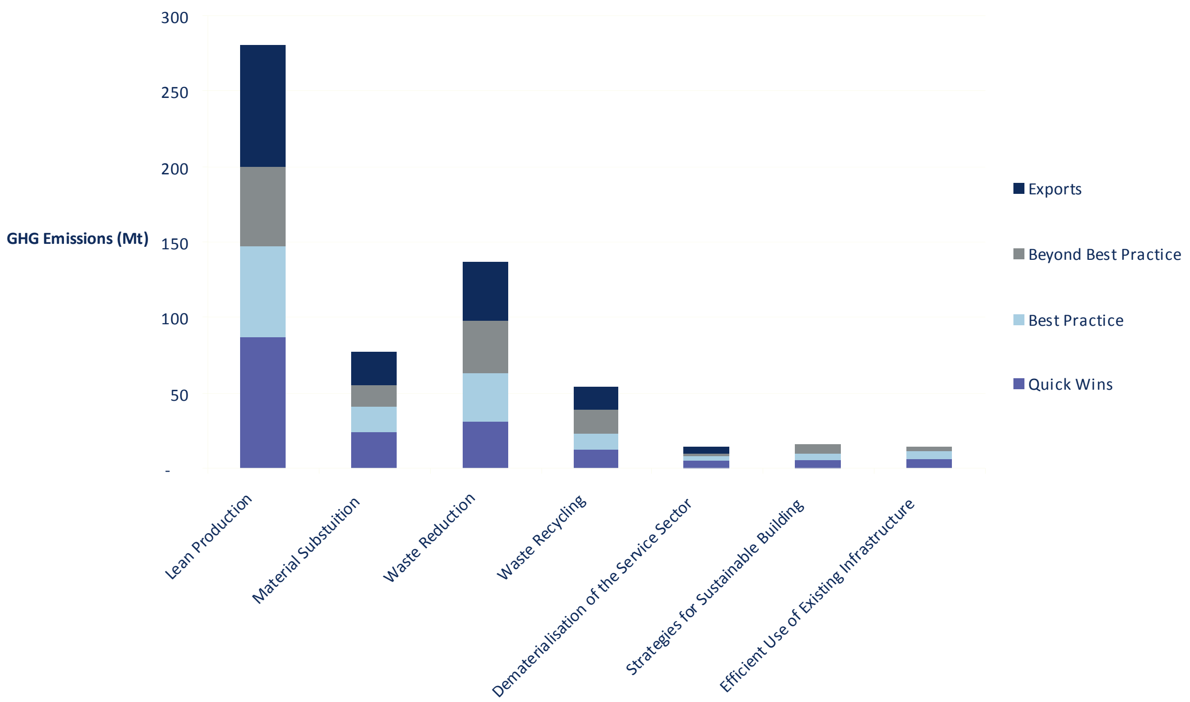
The results illustrate savings from Quick Win scenarios to 2050. Whilst these will be achieved by 2020, we assume the same continues to 2050. When results from the Quick Wins are referred to as 2020, these are cumulative emission savings by 2020. When Quick Win savings are referred to by 2050, these are the cumulative emissions saved over the 46 year time period from 2004 to 2050.

### *5.2.1 Supply strategy results*

Seven different supply-side strategies were analysed at three levels of implementation (Quick Wins, Best Practice and Beyond Best Practice), documented in section 364.3. Figure 19 gives an indication of the cumulative contribution that these strategies could make to reducing UK GHG emissions from now until 2050. As these relate only to UK production, they do not affect the UK's imported emissions, yet will reduce the impact of products that the UK exports. Therefore savings from exports are also shown in Figure 19.

The production strategies that were most effective relates somewhat to the number of sectors that the strategy applied to. For example, the reductions were small in the strategies that related exclusively to the construction sector, compared to Lean Production which affected a wide range of sectors, including construction. While they were effective in terms of achieving GHG emission reduction, overall the savings were considerably smaller.

Figure 19: Cumulative GHG emission savings from supply strategies




The two strategies that achieve by far the greatest reduction in GHG emissions related to “Lean Production” and “Waste Reduction”. The assumption taken with waste reduction related to less material input into manufacturing through better material management. Therefore, it is not about dealing with waste in a more efficient manner, i.e. recycling, but about waste prevention throughout the supply chain. The benefits are clear when compared to the waste recycling strategy. Ensuring almost zero waste by manufacturing sectors by 2050 could guarantee 137 million tonnes less GHG emissions in the atmosphere by 2050. A reduction of 98 million tonnes from domestic products consumed in the UK and 39 million tonnes from domestic products consumed in other countries.

Even more effective is the strategy of Lean Production. Lean production refers to the re-designing of products to reduce material weight, i.e. producing lighter products. This strategy was relevant to a wide range of goods sectors thus creating large scale change in emissions. This strategy could contribute to GHG emission reduction of almost 280 million tonnes by 2050 (200 million tonnes from UK consumption and 80 million tonnes from UK exports) and in the short term (by 2020), reduce cumulative GHG emissions by nearer 20 million tonnes including exports (approximately 6 million tonnes).

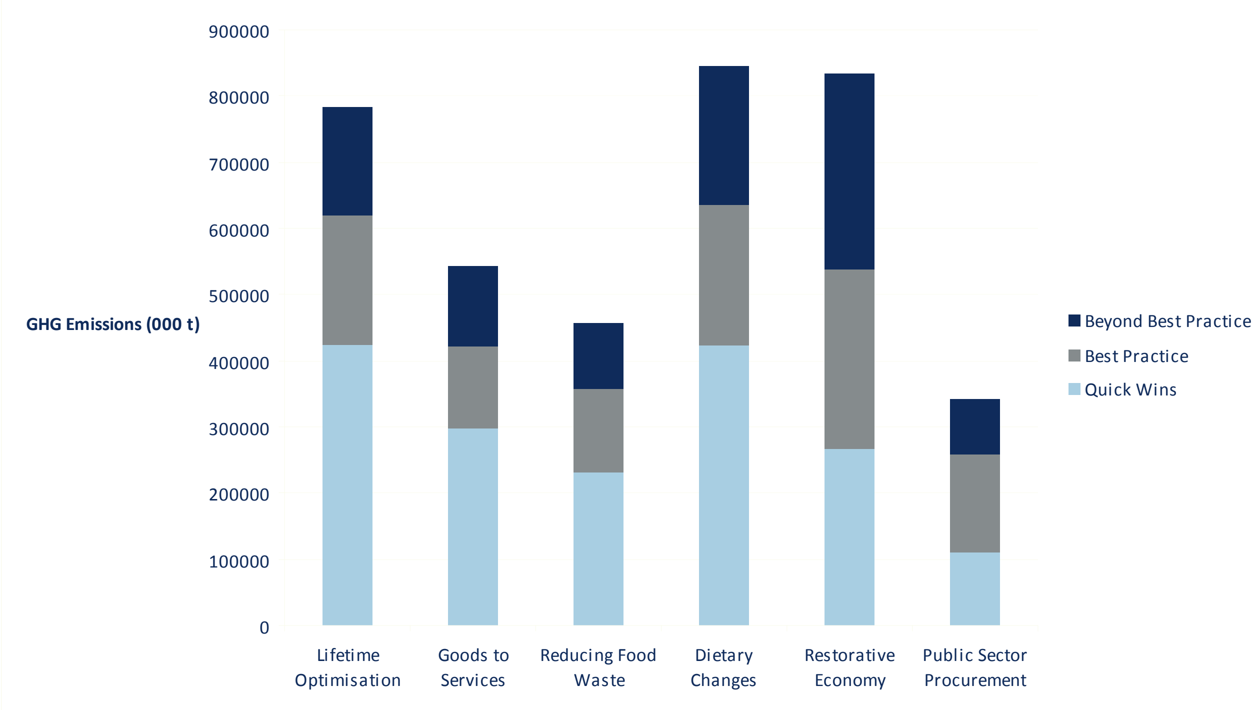
### *5.2.2 Demand strategy results*

Consumption side strategies deliver significantly larger saving (Figure 20). One of the key reasons for this is that consumption side strategies had the ability to affect emissions both in the UK and those associated with imports. As imported emissions are likely to account for over 45% of the UK total GHG emissions by 2050, any strategy that reduces the impact of imports will clearly achieve greater levels of reduction.

Evidently, there is considerable scope for reducing emissions by ensuring that households use material goods for their intended life and do not dispose of the product while they are still useful. This scenario (Lifetime Optimisation) is by far one the most successful strategies and concentrates on reducing the gap between psychological and technological obsolescence. The Restorative Economy can be seen as an extension of this strategy by building better products that last longer. However, it will not be beneficial if products are built to last longer and households continue to dispose of these products while they are still working. Therefore, policies, attitudes and business models must develop alongside.

Whilst there is considerable overlap between the two, the strategies of building more durable products (Restorative Economy) and ensuring that households use them for their full life, promise the greatest reductions, each potentially contributing a reduction in GHG emissions of 800 million tonnes by 2050. The Quick Wins (reduction by 2020), are also impressive, yet varied between the two. The Quick Win Product Lifetime Optimisation strategy can save 63.5 million tonnes by 2020. There is a delay in the benefits of the Restorative Economy as producing more durable products will require more time. 39.5 million tonnes can be saved by 2020.

Figure 20: Cumulative GHG emission savings from demand strategies



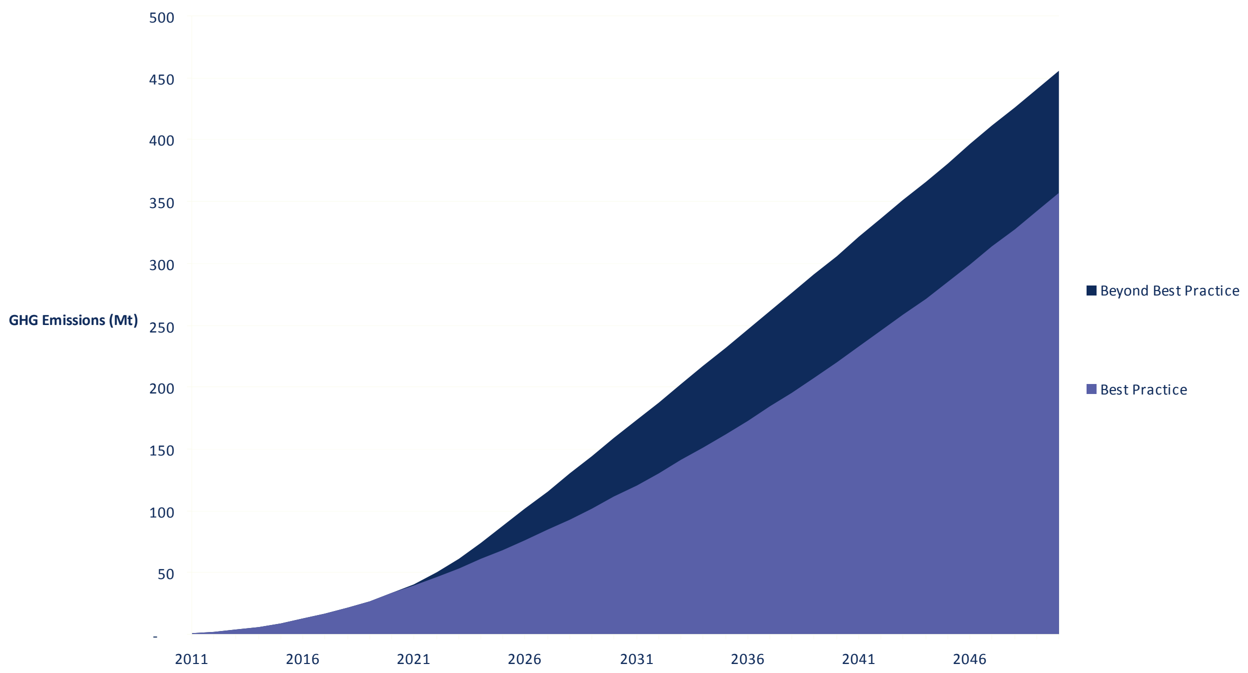

Finally, there is clearly one sector where significant reductions in emissions are possible and this is the food sector. Changing diets to reduce meat consumption can save 846 million tonnes and ensuring that edible food is not treated as waste, a GHG emission reduction of about 456 million tonnes is possible by 2050. Changing diets clearly achieves a larger reduction, mainly because it achieves reduction in meat processing, one of highest carbon intensive sectors in the UK. At the same time achieving such a large shift in consumer preferences is not an easy task, but simple steps can be taken in the short term, for example vegetarian events catering, with the government leading by example.

In terms of cutting out edible food waste, a relatively simple task that will save the householder money, a 50 percent reduction in household edible food waste by 2020 would deliver a saving of 27 million tonnes of GHG emissions by 2020, a total of 232 million tonnes cumulatively by 2050.

### *5.2.3 A comparison of the timescale for implementation*

Using the example of food waste, we illustrate that there is clearly an advantage in early implementation of strategies (Figure 21). This example shows the cumulative emissions saving of avoiding all edible food waste by 2050 (Best Practice) compared to fulfilling this intervention 20 years earlier by 2030 (Beyond Best Practice). Both scenarios achieve the same goal, the difference being the final year by which this goal is achieved.

Figure 21: Comparison of cumulative emissions from eliminating edible food waste by 2050 (Best Practice) and 2030 (Beyond Best Practice)

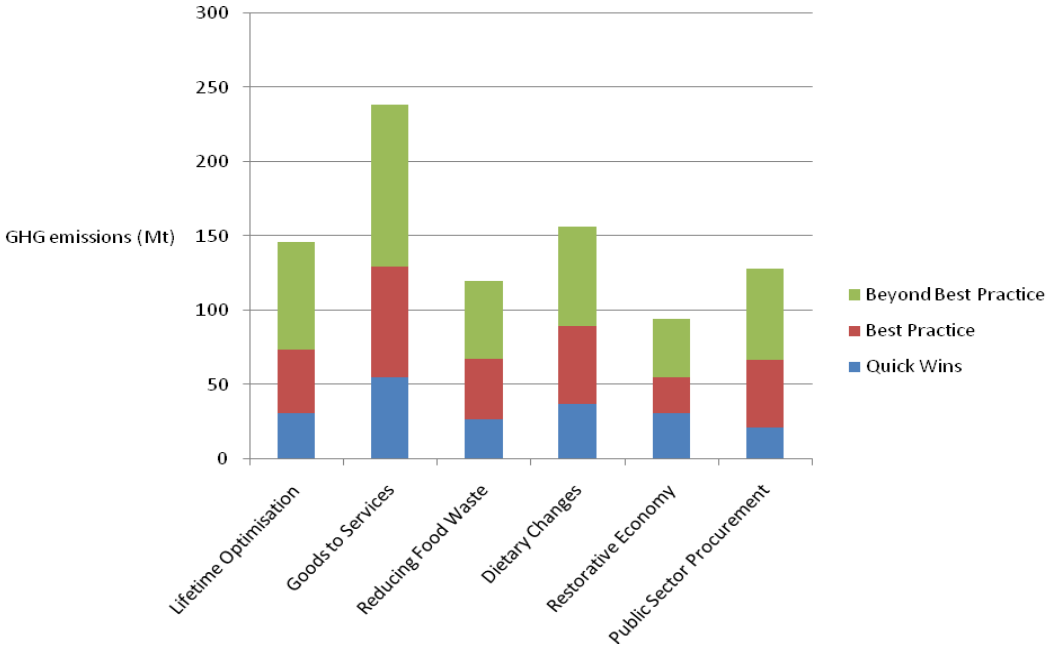



Early implementation (i.e. Beyond Best Practice) prevents an additional 100 million tonnes of GHG emissions in the atmosphere by 2050. Therefore, if over the next 20 years households in the UK didn't throw away edible food, a total of nearly 0.5 billion tonnes of GHG emissions would be avoided. If implementation was delayed, these additional emissions would need to be reduced somehow, showing a clear message that immediate action will make it easier for the UK to meet its ambitious targets by 2050.

### *5.2.4 UK territorial emission accounting*

In terms of previous international reporting agreement for GHG emissions, a territorial approach has been adopted. Therefore, the savings achieved in the consumption side strategies that reduce the impact of imports would be attributed to the country of production and not the UK. While the overall goal is a global reduction in GHG emissions, individual countries are keen to know what strategies will deliver a reduction in emissions related to the target adopted under international agreements. In the production side strategies all the reduction is achieved from the UK's territory. This is not the case in the consumption strategies, which are now presented in Figure 22 as savings from goods and services consumed in the UK from UK production only (i.e. excluding imports).

Figure 22: Cumulative territorial GHG emission savings from consumption side strategies



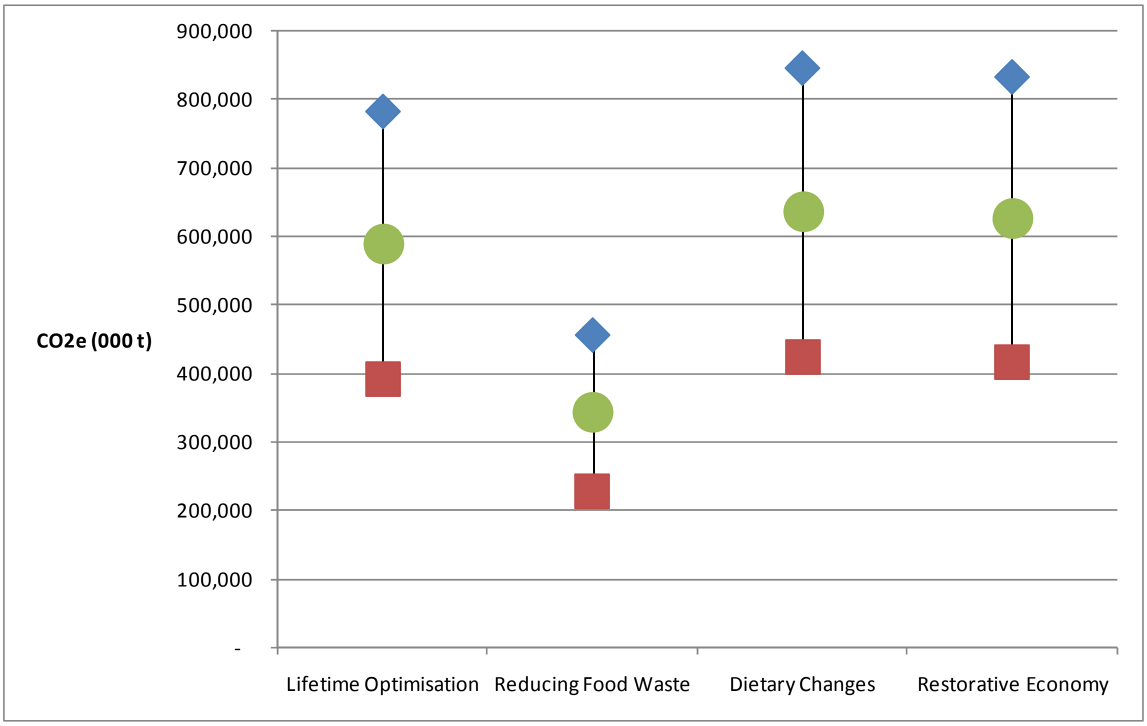

There is a clear shift in the effectiveness of the strategies. This relates mainly to the percentage of the sector that relates to territorial and imported emissions. Goods to Services shifts become the most prominent strategy, compared to longer lasting goods and changes to food consumption patterns. Services however are mainly provided domestically, whereas much of our food comes from abroad. It is important to remember that the aim is to reduce the total tonnes of GHG emissions in the atmosphere and not just achieve reduction in areas where emissions have been assigned to the UK. It would be a preserve policy to ignore the impact of the three most effective strategies (lifetime optimisation, dietary changes and restorative economy) to purely achieve greater territorial reduction.

### *5.2.5 The rebound effect*

Finally, the issue of rebound effect becomes very important when changes have been made in the final demand composition of household spending. Clearly some of the policies will deliver savings for households that could be re-distributed to other product groups. There is considerable uncertainty associated to which product groups the additional money might be spent on. There is also the added difficulty that if the durability of products improved that the price of the product would change. It would be made to a higher standard and to maintain profitability in the sector the price would increase.

In this analysis the rebound effect has been explored through allocating household savings to a range of service sectors. Four strategies are most likely to be affected by rebound effects. Figure 23 gives an indication of the potential scale of these rebound effects.

Figure 23: Impact of the rebound effect on four demand strategies




The bottom of the line (represented by a square) shows the potential reduction in the four strategies if the rebound effect is at its strongest (i.e. a worst case scenario). In this case the additional money has been allocated to a range of service related products that are rising most sharply in terms of consumption from now until 2050. On average this equates to a 50% reduction in the potential savings of the strategies. The circle calculates the rebound effect with the added assumption that price rises will occur in the product groups where most effected, meaning that a 25% reduction in the potential impacts of the strategies would occur. Finally, the diamond suggests that there will be no rebound effect, or at least policies are introduced to ensure that this is the case.

It is difficult to be precise about quite what the effect will be, but important to acknowledge that there will be some rebound consequences to the policies and that fiscal policies are required to ensure that these are minimised.

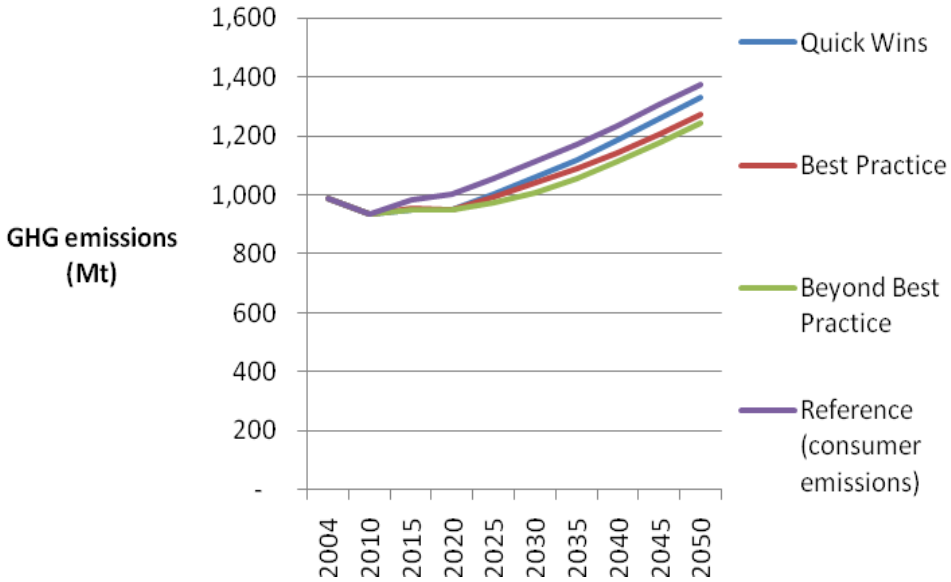
## 5.3 Collective contribution to emissions targets

This section presents the overall contribution different levels of intervention of resource efficiency and sufficiency strategies can make to reducing UK GHG emissions. The individual strategies are combined, removing any overlap.

### *5.3.1 Consumer emission accounting*

Figure 24 gives an indication of the emission pathways of the three collective scenarios (see appendix 1c for results by product group). It is important to remember that these scenarios affect only goods and service sectors representing 32% of UK emissions in the reference scenario.

Figure 24: Benefits of resource efficiency and sufficiency scenarios, emission levels

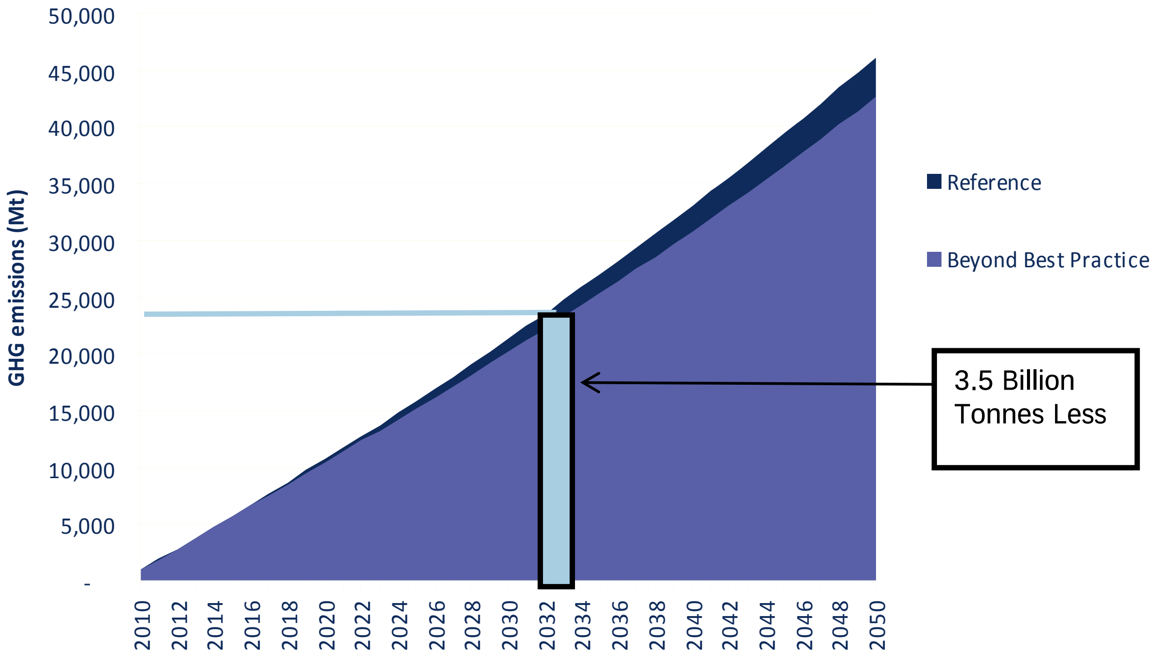



As a percentage reduction from UK consumer GHG emissions in 2050, the quick win scenario reduces the levels of emissions by 3%. Quick Win policies stop at 2020 and growth beyond this reflects mainly increasing demand. The best practice scenario would deliver nearly an 8% saving and the beyond best practice scenario delivers almost a 10% saving.

From a cumulative perspective, the Quick Win scenario would ensure a total GHG emissions saving of 1.8 billion tonnes by 2050 (4%). If Best Practice was achieved across all the goods and service sectors, this would deliver savings of 2.7 billion tonnes (6%). Finally, the Beyond Best Practice scenario would deliver savings of 3.5 billion tonnes (8%) by 2050, almost double that of the Quick Wins.

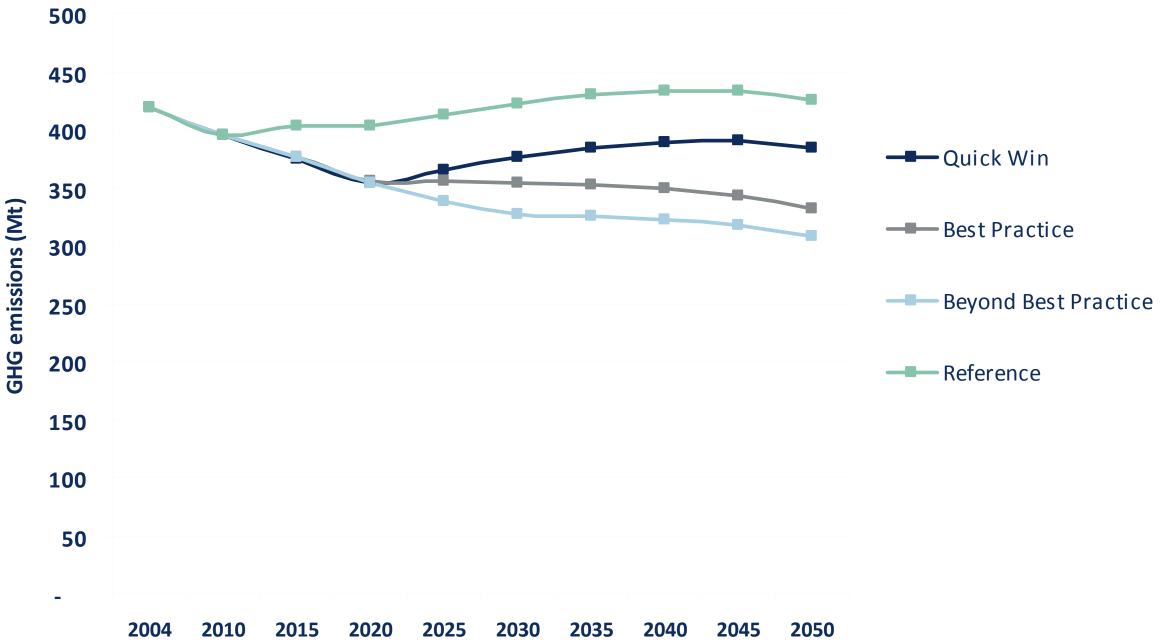
To understand the cumulative GHG emission savings Figure 25 identifies the 3.5 billion difference between the reference scenario and beyond best practice scenario. Without the resource efficiency and sufficiency measures, the UK will use its carbon budget up by 2031. With the measures in place, the UK's carbon budget is extended by two years equating to a total saving of 3.5 billion tonnes.

Figure 25: Total cumulative GHG reduction from Beyond Best Practice




While this may seem small, it is important to recognise that the study did not explore the savings in raw material sectors, transport or energy sectors. Instead it concentrated on the production of goods and services that account for 32% of total emissions by 2050. To get a clearer perspective on the scale of change achieved, we look exclusively sectors that were affected by the measures (Figure 26). From the goods and service sectors, the quick win scenario delivers savings of 9% by 2050. The best practice provides a saving of 22% and beyond best practice a saving of 28%.

Figure 26: Cumulative GHG emissions of goods and service sectors



### *5.3.2 Territorial emission accounting*

As climate change targets currently relate to UK territorial emissions, we provide results from territorial emissions to see the contribution to long and short-term government climate change targets. We do not have as much detail as the consumption perspective, as the study focused on consumer emissions.

From a territorial perspective, implementation of the 13 strategies, achieves a 2% reduction from the UK Territorial Reference Scenario if all Quick Wins were effective. Achieving Best Practice increases this reduction to approximately 3%, and at most they can achieve just over 4%. This is considerably lower than the consumer perspective as the starting point of emissions is lower.

The UK Low Carbon Transition Plan sets out a roadmap for achieving an intermediate GHG emissions reduction goal of 18 percent from 2008 levels by 2020. Whilst we were unable to include these specifically in our analysis, if the Quick Win strategies were achieved by 2020, resource efficiency improvements could deliver 9% of the required reduction.

# 6.0 Conclusions

There are many conclusions from undertaking this work, some very specific to the scenario analysis, others related to the broader role of resource efficiency in climate change. Conclusions from the historic trends, which provided part of the evidence base for the scenarios are contained in chapter 3.0. We present this section in three stages: first the conclusions relating to the results of this study, which incorporates the reference scenario, strategies and collective scenarios; followed by conclusions to the broader role of resource efficiency and finally recommendations for further research and work required to ensure the full potential of resource efficiency is realised.

## 6.1 Conclusions related to the study results

- From a consumer accounting perspective the UK's GHG emissions are going to increase in the future by approximately 0.7% a year. The economic recession has caused an emission decline in the short term, yet projected economic recovery causes an upward trajectory to continue to 2050. The majority of this growth occurs in imported emissions due to both the shift of manufacturing to other countries and meeting increasing consumer demand from products abroad.

- Transport is responsible for the highest growth in emissions, emitting over a three fold increase in GHG emissions. All other high level sectors except for goods manufacturing show a more moderate rise in emissions, with goods in decline, estimated at an 11% reduction by 2050. There will be variation within these sectors.

- From a territorial perspective, without further policy action UK GHG emissions are projected to grow at approximately 0.4% per year. Again, transport is responsible for the most rapid emission increase, with all sectors growing to a lesser extent. However, when accounting for service provision from UK supply chains only, emissions from services are in decline.

- Assuming a target of 80% reduction from 1990 consumer emissions, from a cumulative emissions perspective the UK will have used up its carbon budget by 2031, with any further emissions released into the atmosphere beyond this being additional to the UK's budget.

- From the strategy results, wide reaching strategies that affect a large number of sectors generally achieve the highest reductions. Unless affecting one of the few highest impacting goods and service sectors, for example meat processing, changes at the individual sector level do not make significant emission savings.

- Lean Production is the most promising supply-side strategy, when applied to a wide range of goods, by reducing material flows through the economy. Up to 280 million tonnes of GHG emissions can be prevented from entering the atmosphere by 2050.

- The results clearly demonstrate that adopting the waste hierarchy, where the need for the material or good is first eliminated, yields higher benefits than treating the waste.

- Consumption strategies have the potential to make bigger emission savings as they affect the supply of not only domestically produced products but also those produced abroad for UK consumption. Caution needs to be taken when the results for demand-side strategies are taken from a territorial perspective as accounting for only the consumption of domestically produced products changes the pattern of effectiveness of the different strategies and will yield less global savings. This highlights the difference in the type of goods and services produced in the UK with those the UK imports instead.

- The most effective strategies related to changing household behaviour are in three key areas. These include the purchasing of more durable products, using products until they can no longer function and for changing diets to reduce meat and dairy consumption. At best, these strategies can save around 800 million tonnes each by 2050.

- The benefits of early implementation are clear and delaying action means additional emissions will build up in the atmosphere which would need to be reduced by some other way. Achieving targets earlier reduces the scale of reductions needed in the future.

- The rebound effect demonstrated that approximately 50% of the benefits of resource efficiency and sufficiency could be lost.

- Over the next 10 years there are significant opportunities for resource efficiency and sufficiency to contribute to reducing emissions. If every “Quick Win” option was implemented, over 254 million tonnes of GHG emissions could be avoided between 2010 and 2020. This equates to annual reductions of 25.4 million tonnes.

- If all the strategies are implemented to their full potential, resource efficiency and sufficiency could contribute nearly 10% reduction in GHG emissions against the reference scenario in the UK by 2050. Reductions from the UK’s territorial emission account can deliver just over a four percent saving.

- Within the goods and services sectors influenced in the analysis, which represent 32% of emissions in 2050, the resource efficiency strategies identified in the report could deliver up to a 28% reduction in GHG emissions of goods and services.

- The analysis shows that there is not much to gain in implementing the “Beyond Best Practice” scenario above the “Best Practice” scenario.

## 6.2 Broader conclusions of the role of resource efficiency and sufficiency in climate change

- Material Efficiency alone cannot deliver an 80% reduction in GHG emissions by 2050. However, it could clearly be part of an overall strategy that additionally recognises the need to decarbonise the electricity sector and achieve deep cuts in the transport sector. The necessary change is so substantial that every sector has to respond to the climate change crisis, including the product sectors.

- By taking a cumulative emissions approach, the analysis clearly demonstrates the advantage of early implementation in reducing GHG emissions. Delaying action will impact significantly of future rates of emission reduction.

- In the short-term, whilst infrastructural barriers prevent energy realising substantial emissions reductions now, there is a strong advantage for resource efficiency to deliver immediate savings. This would delay the time scale for the UK using up its carbon budget, and reduce the scale of reductions needed beyond 2020.

- The most effective strategies relate to changes in consumption patterns of UK households. Each consumption side strategy delivered a greater saving than every production side strategy. The key reason for this is that consumption strategies have the ability to reduce emissions abroad where production side strategies are limited to the UK economy. As the UK continues more and more to rely on overseas production there is a need to improve resource efficiency in rapidly developing countries.

- The results support that reducing material requirements by industry is a more successful strategy than managing waste more effectively.

- Each production side strategy drives resource efficiency in a selected sector and therefore delivers a cost reduction in that sector. Whilst in this respect each strategy offers the dual advantage of reducing emissions and reducing costs, the demand for material sectors will decline. The economy will respond and adjust, simply redistributing money across different sectors.

- Climate change is not the only key environmental issue. Many, if not all of the strategies, will deliver co-benefits related to many other environmental issues such as resource scarcity, other pollutants and water consumption.

## 6.3 Recommendations

- Prioritise “Quick Wins” and develop a UK strategy for immediate implementation.

- There is a lack of evidence on the possible changes in resource efficiency within industry. This study would have benefited from a greater insight into the role of industry in resource efficiency and the potential for change. There is a need for detailed industry knowledge to understand the feasibility of resource efficiency strategies to individual sectors.

- While all these strategies can be implemented with no significant effect on the overall UK economy, each strategy will cause a structural shift in the economy and there will clearly be winners and losers. Support is needed for industry and consumers to achieve this transition towards a low carbon economy.

- Material efficiency, along with other non-energy related strategies, must be incorporated into UK climate change scenarios, which is currently not the case.

- A greater knowledge of the right policies to counteract the re-bound is required to ensure that all the resource efficiency and sufficiency strategies have their intended effect.

# Appendix 1: Reference, strategy and scenario results

Please refer to the accompanying excel workbook containing Appendices 1a, 1b and 1c.

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