Final Report

Securing the future – The role of resource efficiency

This report quantifies how resource efficiency actions, as well as reducing greenhouse gas emissions, can reduce abstracted water, ecological footprint and the use of specific resources.

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Front cover photography: Globe from space

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Executive summary

In 2009 WRAP (Waste & Resources Action Programme) published 'Meeting the UK Climate Challenge: The Contribution of Resource Efficiency', the UK's first research into how resource efficiency can help the UK meet its climate change targets. The report showed that implementing 13 quick win resource efficiency strategies – see Table 1 below - could contribute as much as 10% of the target reduction in UK domestic greenhouse gas (GHG) emissions by 2020 as required by the Low Carbon Transition Plan. There would also be additional reductions in GHG emissions outside the UK associated with changes in UK consumption of products manufactured abroad.

Table 1 Production and consumption strategies

Production strategies	**Consumption strategies**
■ Lean production (e.g. light weighting) ■ Material substitution ■ Waste reduction ■ Waste recycling ■ Dematerialisation of the service sector (e.g. implementing resource efficiency measures) ■ Sustainable building (e.g. new build) ■ Efficient use of existing infrastructure	■ Lifetime optimisation (e.g. using goods for their technical lifetime) ■ Goods to services (e.g. renting instead of buying some products) ■ Reducing food waste ■ Dietary changes ■ Restorative economy (e.g. reuse and refurbishment) ■ Public sector procurement

Climate change, whilst important, is not the only environmental issue of concern. Resource availability, water use and our ecological footprint (how many planets we require to support our lifestyles) have been raised at a UK and international level. These global environmental issues translate to UK economic security issues. For example, the Strategy for Sustainable Growth (BIS, 2010) highlights a need to maximise our effective use of scarce natural resources, whilst the recent National Security Strategy (HM Government, 2010) has identified a tier 3 risk of short to medium term disruption in international supplies of resources essential to the UK (e.g. food and minerals).

This new report assesses the ways in which the same 13 quick win resource efficiency strategies identified in the 2009 report could address these wider environmental and economic security concerns. It examines the extent to which these resource efficiency strategies that reduce UK GHG emissions could also reduce UK's water use, UK's reliance on specific materials and UK's ecological footprint.

The specific materials chosen for this study were: iron ore and steel, wood and pulp products, plastics, fertilizers, aggregates, aluminium, gypsum and plaster products, copper, cobalt, lithium and rare earths (rare earths are a group of 17 metals that are used in specialist applications such as magnets, as catalysts in petrol, IT equipment, TVs, glass and ceramics, and are only mined and produced in a few parts of the world).

It should be noted that this research has attempted a novel way of modelling the resource inputs, flows across industrial sectors and the final outputs. In this report, environmental issues have been modelled consistently at the macro-economic level, and represent the first known attempt to incorporate physical data into a model which tracks the movement of materials through the UK economy. This innovation and some of the data quality on materials has made this approach challenging; however, all limitations and future recommendations are outlined in the report.

The keys conclusions are that:

- as well as reducing GHG emissions, implementing the 13 quick win resource efficiency strategies can significantly reduce our use of non fossil fuel resources, water and our ecological footprint. No conflicts were identified in the research;
- the UK currently uses around 260 million tonnes per year of the selected materials in this study. By 2020, our use of these could be reduced by over 38 million tonnes per year (15%) against baseline projections. This is in addition to avoidable food waste identified in previous WRAP research;
- our reliance on some of the specific materials, such as rare earths, cobalt and lithium, could be reduced by 10-25% by 2020 through implementing these strategies;
- water abstraction associated with UK consumption could be reduced by almost 6% by 2020 against baseline projections; and
- the ecological footprint (the number of planets we require to support our lifestyles) can be reduced by 5-7% by 2020.

Clearly, improving resource efficiency can make a significant and positive impact on a range of environmental issues. However, implementing certain strategies or working on certain sectors can allow a focus on a particular environmental issue.

For example, for most of the materials selected, the biggest impacts can be attributed to four resource efficiency strategies; lean production (i.e. making goods with a lower material requirement); waste reduction (i.e. reducing waste in manufacture and commerce); lifetime optimisation (i.e. reducing the amount of working products thrown away) and goods to services (i.e. increasing the proportion of some products which are leased). Within these four resource efficiency strategies, those which influence the throughput of electrical goods affect many of the materials selected.

The greatest savings on material use comes from aggregate use. This is because the overall quantity of aggregates used in the UK economy is so much greater than all other materials assessed.

In a similar way, consumption strategies such as reducing food waste dominate the water use.

It is important to note that the 13 resource efficiency strategies were identified to consider the relationship between climate change and resource efficiency. They were not chosen to consider how best to reduce the use of water or the specific materials chosen. This means that the strategies used in this research have not covered particular sectors and products, where there may be additional resource savings.

It should also be noted that these results are based on quick win strategies and do not include consideration of changing technology e.g. an increase in hybrid electric vehicles would actually lead to an increased demand for lithium. A more detailed analysis of individual indicators would be required to take such technology developments into account.

Conclusion

The report confirms that quick win actions taken to improve our resource efficiency have complementary benefits of reduced GHG emissions, resource use, water use and ecological footprint. It also confirms the findings of the previous study that both production and consumption strategies are important for addressing these environmental issues.

It also shows that resource efficiency could have an important role to play in addressing resource security issues that are increasingly under debate.

Contents

Glossary

Apparent consumption: Used to define the consumption level of material by industry, usually calculated by: Production - Exports + Imports
Consumption level: Level of consumer spending (£)
Ecological footprint: An environmental indicator: the total area of productive land and water ecosystems required to produce the resources that the population consumes and assimilate the wastes that production produces, wherever on Earth that land and water may be located (Rees, 2000)
Final demand: Final demand includes consumption by households, government and not for profit institutions serving households
GHG: Greenhouse gas emissions, measured in Co$_2$ equivalent
Intermediate or inter-industry demand: The demand for products by industry from other industrial sectors of the economy
Multi-regional input-output model (MRIO): A MRIO model assigns emissions produced throughout complex global supply chains to final products
National Footprint Accounts (NFA): Direct land or resource use associated with different activities, by country, as calculated by the Global Footprint Network
ONS: Office of National Statistics, UK
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
PIOT: physical input output table
Production intensities: The environmental impact generated 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.
Resource efficiency: supply-side measures that tackle inefficiencies across supply chains; overuse of resources and waste when products and services are produced. Being more material resource efficient means using less to produce the same level of output
Resource sufficiency: consumption or demand-side indicator that considers whether the product or service is required; doing without as opposed to the efficient use of more products
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
TSB: Technology Strategy Board
WRAP: Waste & Resources Action Programme

1.0 Introduction

1.1 Background to the study

In 2009 WRAP published 'Meeting the UK Climate Challenge: The Contribution of Resource Efficiency' ('the 2009 report'). This is the UK's first research into how resource efficiency can help the UK meet its greenhouse gas (GHG) reduction targets. The report shows that making better use of our natural resources could contribute as much as 10% of the target reduction in UK domestic GHG emissions by 2020, with additional reductions associated with changes in consumption of products from abroad. The report also projected forward the contribution of resource efficiency to reducing GHG emissions up to 2050.

Climate change, whilst important, is not the only environmental issue of concern. WRAP therefore sought to understand the impact that the 13 resource efficiency strategies identified in the 2009 report could have on a range of other impacts, specifically resource use, water use and ecological footprint. The reason for selecting these indicators is discussed below.

1.1.1 Drivers for considering resource flows

The 2010 Strategy for Sustainable Growth (BIS, 2010) highlights a need to maximise our effective use of scarce natural resources, whilst the recent National Security Strategy (HM Government, 2010) has identified a tier 3 risk of short to medium term disruption in international supplies of resources essential to the UK (e.g. food and minerals). The ONS Environmental Accounts for the UK (ONS, 2010) show that in 2008 the sum of materials taken from the UK environment for economic use (total domestic extraction) was 524 million tonnes. Domestic extraction has fallen in every year since 1999 and by 25% in total since 1990. It is now at the lowest level since records began (1970). At the same time our total material requirement has remained broadly constant since 1990. This means that we are increasingly reliant on goods produced using materials imported from abroad to meet our requirements.

As the world economy grows, competition for resources increases, with environmental and economic implications. The EC recognised this and identified materials of concern in the 2004 publication 'Towards a Thematic Strategy on the Sustainable Use of Natural Resources', focusing on high volume renewable resources. However, the debate on resources is not well served by tonnage figures alone, as many materials used in small quantities are considered of strategic importance. This was highlighted by the 2010 report Critical Raw Materials for the EU.

The resources we rely on for our economic well being are renewable (e.g. wood) or non-renewable (e.g. metals). However, both of these are finite, as renewable resources can only be replenished at a certain rate. If we exceed this rate, the resource becomes depleted. Furthermore, in addition to physical limits, there are a range of other constraints such as geopolitical vulnerability, ecosystem functioning and social issues (Tukker et al. 2006).

In this context, and one of increasing global competition for resources, inefficient use can lead to negative economic and environmental impacts worldwide. This study therefore considers ways in which we can reduce our reliance on selected resources of concern through more efficient production and use of goods and services.

1.1.2 Drivers for considering water

In the Water Footprint of the UK (2008), the WWF identified that whilst the average UK individual directly uses around 150 litres per day, the products we buy, including food, account for an additional 4,645 litres of water every day. Around the world, extraction of water from rivers, lakes and aquifers at a rate which exceeds their replenishment (e.g. through rainfall) causes water stress, leading to social and environmental issues.

The UK Government set out its vision for a sustainable and secure food system in Food 2030, (Defra 2010), preceded by the Scottish Government food and drink policy (Scottish Government 2009). Appropriate water use is an implicit part of both of these strategies.

Future Water (Defra 2008) sets out the Government's water strategy for England. This focuses on water abstraction, rather than water footprint. This includes targets to reduce the demand for mains water to 3m^3 per person per year by 2020. The Food Industry Sustainability Strategy (FISS), launched in 2006 to improve environmental, social and economic performance, challenged the food industry to reduce its current levels of water usage by setting the industry an overall water reduction target of 20% by 2020, against a 2007 baseline.

Reduction of business water use is also important. An understanding of ways in which resource efficiency could contribute to a reduction in water use by commerce and industry is also essential. Water use is not the same as a water footprint, which also takes account of what happens to water once it has been used, and includes additional sources of water (e.g. rainfall).

1.1.3 Drivers for considering ecological footprint

If everyone in the world lived as we do in the UK, we would require 3 planets to sustain our lifestyles (WWF, 2006). Reducing this to a sustainable level is a one of the Welsh Assembly Government's five headline indicators of sustainable development in Wales. As part of this, the Welsh Assembly Government has designed strategies to give possible footprint routes from 2001 to 2020. This research complements the existing Welsh Assembly Government work, and also considers the implication of resource efficiency on the ecological footprint of the UK.

1.2 Project aims and objectives

Concerns about resource availability, water use and the ecological footprint of the UK have been raised at national and international levels. However, unlike for GHG emissions, there is no quantified long-term political goal to influence these at present, either at an EU or UK level. Consequently, this report does not model these indictors up to 2050 as in the 2009 report; it instead focuses on the arguably more certain short-term trends and policies. It will use the basis of the 2009 report, investigating the impact that a range of quick win resource efficiency strategies will have on a number of resource use, water use and ecological footprint between now and 2020.

The aim of the project was to quantify the contribution that the resource efficiency strategies previously identified could make to reducing UK demand for specific materials, our requirement for water and our overall ecological footprint.

Prior to this study there was no single complete data source and method available with which this investigation could be undertaken straight away. As a result this study contributes to the understanding of environmental indicator data and the modelling of this data in the future. The project therefore consisted of three phases:

- To investigate data availability for resources, including water, and ease of application into economy-wide models.
- To draw conclusions about how the resources data could be best collected and analysed in the future and what information this could provide.
- To explore the impact of resource efficiency strategies on a resource use, water use and ecological footprint.

This report provides a starting point for exploring how a number of environmental resources could be modelled consistently at the macro-economic level. It also provides an insight into the potential for combining a number of environmental indicators into one model, highlighting any resource conflicts or co-benefits that could arise from one strategy.

1.2.1 Defining resource efficiency and sufficiency

This report considers both material resource efficiency and resource sufficiency. It is important to make the distinction between these two terms for this report as it determines the scenario approach.

- **Resource efficiency** refers to the production or supply-side measures that tackle inefficiencies across supply chains; overuse of resources and waste when products and services are produced. Being more material resource efficient means using less to produce the same level of output.
- **Resource sufficiency** is a consumption or demand-side indicator that considers whether the product or service is required; doing without, as opposed to the efficient use of more and more.

Resource efficiency from a climate change or GHG perspective, as defined in the 2009 report, is about generating fewer emissions to provide the same level of output.

Resource efficiency from a materials, water or land perspective is about ensuring that inputs into the production of goods and services are processed as efficiently as possible; gaining the maximum output from minimum resource input.

For brevity, from this point onwards in this report, resource efficiency is taken to mean resource efficiency and resource sufficiency.

1.2.2 Resource efficiency and economic growth and development

The current economic system in which we operate in some ways encourages resource efficiency; at the micro level it is economically desirable to produce greater output with fewer inputs in order to maximise profitability. However, there are a number of reasons that this may not always deliver socially or environmentally desired outcomes. For example, if a by-product of the process does not have a cost or a benefit then it may be ignored; an industrial process may cause the pollution of a river or atmospheric emissions and if these are not financially accounted for in the process they go unchecked (the economic problem of externalities). This problem of externalities, coupled with the difficulties of imperfect markets and incomplete information mean that the most resource efficient choice is not always made.

On a macro level the current system of economic growth falls down on a more fundamental level – continuous economic growth would ultimately be reliant on a continuous increase in resource input, which is unavailable on a planet with finite resources. Even with technological change, any efficiency gains would have to match or outweigh increasing demand in order to maintain or reduce current resource use, especially with population growth and increasing consumer demand.

Delivering both resource efficiency and sufficiency are therefore vital at the micro level, to reduce resource use across supply chains, and also at the macro planetary-wide level. To help deliver a shift in thinking the concept of the circular economy is a useful starting point. This concept is focused on the principle of resource efficiency within production and consumption and adopts the basic principles of “3Rs”: Reduce, Reuse, Recycle (Yuan et al. 2008).

1.3 Project approach

1.3.1 Existing resources data

The mapping of resource flows through the economy is far behind the data, knowledge and mapping of financial transactions. Knowledge of resource inputs, flows through industrial sectors and product outputs is not as advanced as that of financial transactions. Thus tracing resource movements through the economy is currently difficult and time consuming.

Currently, this resource analysis is either completed at the aggregated level of domestic material consumption or on a highly disaggregated individual material level. Neither gives a full picture of resource flow through the economy. Domestic material consumption includes only the primary materials supplied in the UK and consumed by UK industry, which excludes the significant supply of materials from imports and does not give an indication of flows between industries. Individual material assessments provide resource flow accounts for a specific material at a particular point in time, but do not give a consistent understanding of how different resources move through the economic system over time, the interactions between them, or how economic shifts may affect resource use indirectly.

1.3.2 Modelling resources in the future

In 2010, the EU published proposals for resource productivity indicator for Member States (EUJRC, 2010). However, it has been recognised that to understand resource flows within the economy, including scarce materials, there is a need for a more sophisticated form of resource productivity accounting and mapping. In their 2001 report Resource productivity: making more with less, the Performance Innovation Unit (PIU) considered Physical Input Output tables (PIOTs) to be the most promising approach to this issue, as opposed to methods such as Life Cycle Inventories (LCI) and economy-wide material flow analysis. This was because PIOTs provide a detailed presentation of flows between branches of the economy and can provide a better understanding of the underlying reasons for changes. PIOTs also allow users to calculate materials efficiencies per branch of production, and may be used to analyse both the direct material inputs and outputs of economic activities and also the indirect burdens of production and consumption.

Some countries have already developed PIOTs including Denmark (Gravgård Pedersen, O. 1999), Finland (Mäenpää, I., Muukkonen, J. 2001-2008) and Germany (Destatis (Statistisches Bundesamt) 2005). However, to date wider adoption has been constrained by resource and data limitations.

This report is a first attempt to add resource data as an extension to an input-output framework. Two key tasks were required in support of this:

1 a review of available resource data; and
2 an assessment of its suitability for inclusion in the scenario analysis.

Based on available data, the report draws conclusions regarding the effect of different the resource efficiency strategies on a variety of resource, water and ecological footprint indicators, and provides recommendations about how economy-wide resource modelling can progress in the future.

The analysis in this study will be based on the same methodology used for the 2009 report. In practice it involves extending the model to incorporate indicators that are not commonly modelled within that framework, mainly due to data restrictions. From a methodological perspective this study is an important step in this field, expanding the scope of an existing technique beyond common practice. The basic method used and the extensions made are described fully in the methodology section of the report.

2.0 Indicators

2.1 Indicator description

The indicators used in this study and the reasons for their selection are described below.

2.1.1 Water

The water footprint of a consumer is defined as "the total volume of freshwater consumed and polluted for the production of the goods and services consumed by the consumer" (Hoekstra, A.Y et al. 2009). This covers the direct water use in the home of an individual, as well as the water required to grow, manufacture and provide goods and services.

The water footprint of a UK citizen is estimated at 4,645 litres per person per day. Of this, only 3% is due to direct use within the household. The manufactured goods we purchase (including cars, electrical items and clothing) account for 24% of this total. 73% of our water footprint is associated with the agricultural products we consume, principally food (WWF, 2008).

The scope of this report is narrower than a water footprint, focusing instead on water abstracted from surface waters and groundwater for use in agriculture and business. In water footprinting, this water is commonly defined as 'blue' water. This includes water used in the UK to produce goods and services consumed by UK citizens as well as water used overseas to produce products that are imported to the UK, including food. This gives us a picture of how consumption by UK citizens translates to water use not only in the UK but also abroad.

By considering only blue water, the data provided on production strategies in this report should align with government objectives relating to water use by UK businesses. WRAP will produce a separate publication assessing the water footprint of food waste, including all sources of water.

Many of the resource efficiency strategies could indirectly reduce household water use (e.g. reducing food waste, changing the lifetime of water using products). However, the strategies focus on supply-chain efficiencies and demand reduction of products and services, and have therefore excluded water used by households. Water consumption by agriculture and industry has been incorporated into the model to allow us to estimate the volume of water embedded in goods and services consumed by UK citizens.

The analysis herein could be extended to incorporate a full water footprint, including direct household water use and additional targeted strategies. This report is limited to extending the strategies that were developed for the GHG emissions report to other indicators, of which water is one. It is not a full scenario investigation into the total water footprint.

2.1.2 Ecological footprint

The ecological footprint for a particular population is defined as; "the total area of productive land and water ecosystems required to produce the resources that the population consumes and assimilate the wastes that production produces, wherever on Earth that land and water may be located" (Rees, 2000). The ecological footprint is usually described in terms of global hectares (gha). This is a hectare of land with world average bio-productivity – a world-average ability to produce resources and absorb waste.

The most powerful message from the concept of ecological footprinting is that we are currently using up more of the world's resources than we have available. We are placing demands on nature to provide us with food, materials, energy and waste absorption at a faster rate than they can be provided or renewed. It is a strong tool for communicating the urgent need to address unsustainable patterns of our current consumption, a message which can be lost when looking at individual indicators in isolation.

The ecological footprint as a whole is useful for considering the resources that would be required to satisfy consumption and assimilate wastes, but for analytical purposes it is useful to break it down into its different components – the fossil fuel footprint, which is the land required for sequestering the emissions arising from energy generation; and the different land footprints, the physical land (and oceanic) resources used for raw materials.

It is important to consider the scope of the ecological footprint to avoid over-interpretation – there are some things it cannot tell us. It does not account for our consumption of non-renewable (abiotic) resources or the damage that we cause to ecosystems through over extraction and pollution, so it does not show the full impact of our consumption if used in isolation. We would need to consider other complementary indicators to get the full picture of our ability to sustain natural resource to meet our needs indefinitely. In addition, the ecological footprint is an aggregated indicator: it includes both pollution and land use. This can make it difficult to use when making detailed decisions about which resources are most over-exploited, which ecological limits are most threatened or which land should be protected.

The most significant message communicated by the ecological footprint is the concept of overshoot: we are using more resources than the earth can produce and producing more pollution that the earth can absorb. This is an extremely powerful message that can motivate stakeholders. However, the main cause of this overshoot is the land required to absorb GHG emissions from fossil fuel combustion. The concept of overshoot is primarily telling us that human activity is responsible for excessive GHGs in the atmosphere.

2.1.3 Materials

The material indicator is the total quantity of each material embedded in goods and services consumed by citizens in the UK. This includes goods and services produced in the UK (using material imported to the UK as well as that which originates in the UK) and goods produced in the rest of the world that are consumed in the UK. However, it only covers the materials directly associated with these goods: it excludes associated materials (e.g. mining overburden) from the extraction and production process.

To determine the materials of interest for this report, WRAP requested information on specific resource flows in consultation with Defra and the Technology Strategy Board (TSB). The choice of materials was informed by evidence from a number of national and international sources – see Table 2.

In the previous WRAP 2009 report, the production strategies for several sectors were identified as contributing significantly to a reduction in GHG emissions. These same strategies can potentially reduce the use of some large tonnage materials, such as iron and steel, and construction products including cement and plaster. Foodstuffs were not included as WRAP has already completed research in this area, identifying that UK households dispose of 8.3 million tonnes of food and drink per year, of which 5.3 million tonnes is avoidable, with a further 1.5 million tonnes potentially avoidable (WRAP, 2009b). Instead, given concerns over future supply of fertilisers (Cordell, 2010) these have been investigated in further detail.

The 2008 EU raw materials initiative highlights that non-energy raw materials are an essential part of both high-tech products and everyday consumer products. It focuses on mineral (metal) resources. However, their availability is increasingly under pressure (EU, 2010). At the same time, in discussion with the TSB and Defra further materials of interest or concern have been identified, including aggregates and timber products in addition to metals. From these sources, several metals have been selected where data is believed to exist to support analysis, and where they have widespread applications (e.g. cobalt in batteries, in a variety of applications). Aggregates and timber are also included as the EU Thematic Strategy on the Sustainable Use of Natural Resources (EC 2004) identifies the supply of wood and wood derived products as being of concern.

Thus the following materials were considered in this research:

Table 2 Materials of interest and associated report or strategy

Material	**EU (2010) Critical raw materials for the EU**	**Discussion with TSB and Defra**	**WRAP Meeting the UK Climate Challenge**	**EC (2004) Towards a Thematic Strategy on the Sustainable Use of Natural Resources**
Aggregates		✓	✓	
Gypsum and plaster products			✓	
Aluminium			✓	
Copper		✓		
Iron ore and steel			✓	
Wood and pulp products		✓		✓
Plastics			✓	
Fertilizers (nitrogen, phosphate, potassium)		✓	✓	
Cobalt	✓	✓		
Lithium		✓		
Rare earths	✓	✓		

2.2 Limitations of indicators

2.2.1 Data limitations

Material datasets

The overriding limitation of this work and the indicators selected is data availability (see section 3.3). In comparison to the economic or employment data available by sector, resource use data is very sparse, if available at all. The Europe-wide PRODCOM database is a useful starting point, with detailed data about imports and exports of different materials, but information about the use or consumption by sector is limited.

Whilst there are individual studies that provide detailed information about different materials, these only offer a snapshot and are of limited use for macro-modelling, where consistent data is required across a number of sectors.

Water

The formal definition of blue water consumption used in water footprinting is "water permanently removed from a water body in a catchment, which happens when water evaporates, returns to another catchment area or the sea or is incorporated into a product" (Hoekstra, A.Y et al. 2009).

Blue water consumption data that meets this definition is available for UK agriculture but not for UK industry. The only data available for UK industry is total water use or abstraction, which does not tell us how much of the water used is incorporated into a product or required to treat pollution (i.e. discharged as effluent). Although this will affect the results for specific products, given the relative ratio of industrial to agricultural water use it is unlikely to significantly affect the headline results.

Ecological footprint

The direct ecological footprints of production by industrial sector are collated within National Footprint Accounts (NFA) (Global Footprint Network, 2009). These Accounts are equivalent to the Environmental Accounts for the UK, which cover direct emissions by industry. Unlike the emissions dataset, the calculation of direct land use is not UK specific; it is based on a variety of different UN statistics on land requirements and yield factors of different biological resources and product categories. In undertaking these calculations, a number of different sources of data are used and a great number of assumptions have been made. This greatly increases the uncertainty associated with the indicator and assumptions are not consistent across categories. It is calculated in global hectares, where one global hectare (gha) reflects the productivity of a world average bio-productive hectare. A detailed description of the NFA method can be found in Kitzes et al. (2008).

2.2.2 How data limitations translate into modelling limitations

Data restrictions limit the functionality of the model and the analysis that can be done. With extensive datasets this type of model could incorporate many different world regions, for example. There is currently a trade flow input-output model with 113 world regions. However, this requires data for each of those regions in a consistent format. If datasets for a wide range of different environmental indicators were available in a consistent format, for a number of countries, it would be possible to use the model we have used in this project (an extended input-output model) to trace the environmental impact of products consumed in the UK to the specific countries involved in creating the product in question. This could be combined with knowledge of environmental impacts in that region, such as water scarcity or environmental degradation. However, data constraints mean that this is not currently possible and is made extremely complex by the nature of today's global supply chains.

For the purposes of this study, the lack of data for many materials has meant that we have had to assume that the material, water or ecological footprint intensity of a good produced in the UK is the same for other countries in the world. This may often not be the case as carbon intensity demonstrates; the UK has a lower carbon intensity than many other regions of the world, so increasing demand for imported rather than domestically produced products increases the carbon emissions from growing demand even further. This type of analysis for carbon is possible because of the level of data available in a consistent format. Other environmental indicators would need to have this level of data available in order to investigate similar issues.

Data limitations also mean that it is not possible to quantify the uncertainty associated with the results presented in this report. Therefore, only limited analysis of results is possible at this stage.

3.0 Summary of methods

3.1 Background to the modelling approach

This research builds on the model developed for the 2009 report. The previous work was completed using an environmentally extended input-output model, which is a standard economic tool describing the structure of an economy over a defined period of time (usually a year), extended to incorporate environmental information.

The basis of the model is a matrix of all of the interactions that take place between different sectors of an economy. It describes all of the inputs to sectors including labour, products from other sectors, the value added, and all the outputs that they produce in terms of products – hence the name, input-output. It is a model of the entire economy over a specified time period, with all of the movements captured.

An advantage to using this type of system is that it is possible (at an aggregated level) to understand complete product supply chains, because all of the links between sectors are documented. Nothing is omitted in the supply chain sense and consequently the environmental impacts of all stages can be traced and allocated to the final product.

A further advantage of this type of model is that it is not indicator specific. It can be extended to assess the supply chain impacts of any number of indicators, provided the data can be sourced and collated into the necessary format. Part of this study was to investigate the potential for adding a number of new indicators, gathering the necessary data and running them through the model.

Whilst the model is very flexible in terms of indicator extension, it is restricted by the classification system used. Not all indicators will fit into this classification system and will need to be modelled outside the framework. This occurs when the resource or material is a small component of a larger sector. It is possible to disaggregate sectors into sub-groups, but this is usually a lengthy task, beyond the scope of this project. An alternative method called “soft-linking” has therefore been devised in order to make the most of the benefits of the model and include indicators that do not fit directly into the classification system. This method involves taking the outputs from the strategies for only those sectors that are relevant to the indicator and then proportionally applying their impacts to changes in the total material demand over time. This system retains the information about how demand for products will change overtime, whether the strategy directly affects the sector or whether it is indirectly altered by intermediate demand from other sectors that are affected by the strategy.

To date, this type of modelling has only been applied to indicators such as GHGs where the data is more readily available. This project extends the work that has been done so far, applying a recognised and tested method to indicators that have not been analysed in this way before.

3.2 Technical modelling details by indicator

As summarised in the methodological approach section above, there are two principal methods applied for the modelling component of this project: (i) the addition of a new environmental indicator to the existing environmentally extended input-output model and (ii) a soft-linking of other indicators which do not fit into the classification system directly. A full description of the model is provided in the 2009 report.

At the beginning of the project it was possible to identify the indicators which could be added into the model directly and those that would need to be soft-linked using external consumption data to the model’s quick win scenario outputs. This split between indicators is shown in the table below.

Table 3 Indicators identified

Indicators that allocated to the model directly	Indicators soft-linked using external consumption data
Ecological footprint	Gypsum and plaster products
Water	Aluminium
Iron ore and steel	Copper
Wood and pulp products	Cotton
Plastics	Cobalt
Fertilizers (as combined group)	Lithium
	Rare earths
	Aggregates

3.2.1 Method for those indicators allocated directly to the model

In the 2009 report the environmental indicator was GHG emissions by industrial sector. For this study, data on the following indicators will be gathered and added to the relevant sectors: water, ecological footprint and four materials: iron ore and steel, wood and pulp products, plastics and fertilizers.

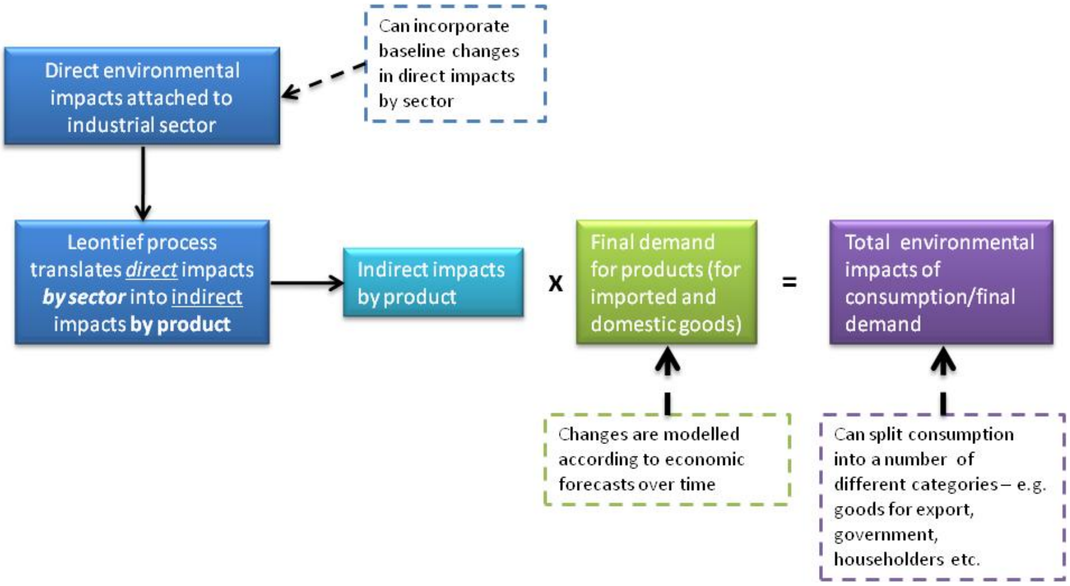
The data for these indicators was collected as the material output from the sector; this is named the 'direct industry impact'. By tracing all of the supply chain interactions in the economy, the input-output model then re-allocates these direct impacts from industrial sectors to the products that are produced. The standard technical framework for this approach is described in section 9.0, Appendix A.

The model calculates the indirect impact embedded within each product group (Leontief process). For example, the indirect emissions embedded within the supply chain of an electronic good, or the indirect amount of water embedded within a furniture product. These factors termed 'intensities' are then multiplied by the expenditure on products to (both domestically produced and imported) to generate the total impact of consumption by indicator. This is shown in Figure 1.

The resource efficiency strategies are run through the model to allow us to consider how any changes to either the intensity or the expenditure will change the total impact associated with consumption for a variety of indicators.

Different datasets are required for the different stages of the model. Both economic and environmental data are required for the full time period that is being considered. It is possible to extract different datasets out of the model at different points, for example, the change in final demand for products is extracted and used for the soft-linking component of this study. Final demand by product will alter according to the overall level of demand in the economy and the strategies that are run through the model. The product intensity will be affected by any underlying historical trends in direct impacts by industrial sector, or any change to intermediate (inter-industry) demand or direct industry impacts in the strategies (see section 5.0 for a description of each of the strategies).

Figure 1 Simplified calculation process of the model

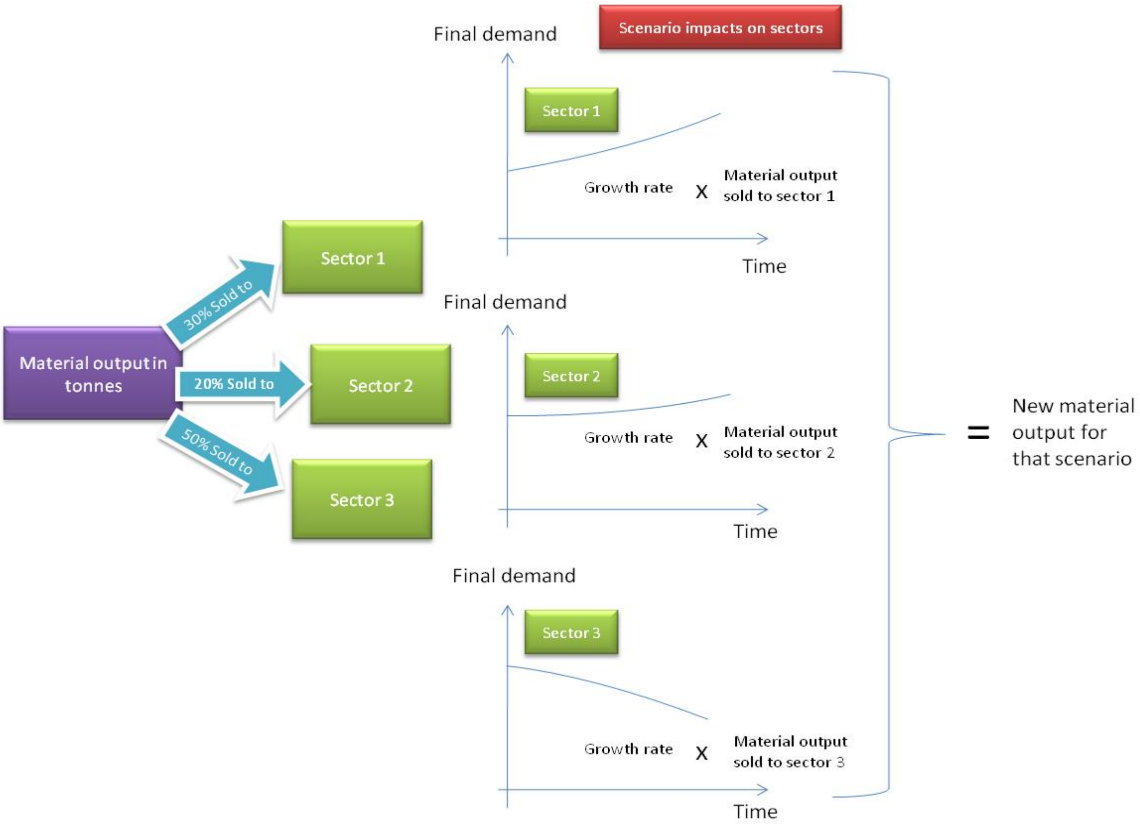


3.2.2 Method for those indicators soft-linked using external consumption data

The second method applies the change in final demand of the sector known to consume the material in question to the total consumption of the material. The sectors that consume the material are identified using a literature review and the change in total consumption of the material is calculated manually, according to the change in final demand by relevant sector that is generated by the model. For example, if the end-use sector for a material is transport, the change to the transport sector as a result of the strategies will be applied to the appropriate proportion of the material consumed by the transport sector. This method relies on the sourcing of material consumption data, split by end-use sector. The initial component of this study investigated whether these data are available in the necessary format.

An inherent assumption in this process is that the change in final demand by sectors that are known to consume the material will result in that sector requiring more (or less) of the material in question. The method with which the calculations are completed is shown in Figure 2.

Figure 2 Soft-linking scenario method



3.2.3 Dealing with imported goods

It important to note that the modelling approach used in this report accounts for the impact associated with goods consumed in the UK that have been produced in the UK and also with those imported from overseas for consumption in the UK. Due to lack of data about the material intensity of products produced abroad we have assumed that they have the same intensity as the UK products. The impact of imported goods is calculated using the following steps:

- The material intensity of UK goods is calculated using the methods described above (see Figure 1).
- The demand for imported products by UK residents is extracted from ONS input-output tables.
- The material intensity is multiplied by the demand for imported products.

This method takes full account of supply-chain impacts for both domestic and imported goods, but could be enhanced by having data on the material intensity of products produced abroad. The flexibility of the framework means that the modelling can expand to fit any number of datasets, for example if you had access to the intensity of production in 100 world regions the model would accommodate this. Due to the large data available for carbon emissions this method has been applied in a 113 world region model, with different carbon intensities for each region. However, the data for materials, water and ecological footprint intensities of production lags far behind, with insufficient data for this type of expansive multi-region analysis.

For the resource efficiency strategies, if demand for imported products is reduced (through the consumption scenarios) there will be a corresponding reduction in the impact from imported goods (and the total impact of consumption). However, supply-side strategies can only affect UK production (since overseas production is outside the control of the UK government) so there will be no reduction in the impact of imported goods and products.

3.2.4 Modelling summary

The extent to which either of these methods (soft-linking or directly allocating to the input-output model) can be performed is dependent on the data that is available. The largest limitation for this method is lack of data. The risks and potential impact on the findings for each indicator are discussed individually. Cases where lack of data undermines any conclusions that could be drawn will be highlighted and discussed fully in the results section. In all cases our confidence in the data will be discussed and any sources for error identified. To reduce this risk as far as possible, we have investigated a number of different datasets, selected data from the same source wherever possible and used alternative datasets to verify our findings.

3.3 Baseline data collection method

Up-to-date GHG data by industrial sector existed for the previous study. No equivalent datasets were available for the indicators used in this study. Therefore, a central part of this project was to find and collate accurate data for each indicator in the model. The data collection process is described in more detail for each indicator set below. All of the data sources and the final figures used are described in section 10.0, Appendix B.

3.3.1 Water data

Blue water consumption data has been collected for the agriculture sector from the UN's Food and Agriculture Organisation (FAO), which has been used in several references below. The water data are calculated by multiplying the water requirement per hectare of different crop products (i.e. wheat, barley) by the total crop areas. The blue water consumption for livestock are calculated based on the method in Chapagain, A.K., Hoekstra (2003). However, the water consumption only include animal drinking and service water, as the water from animal feed will be captured in the environmental input-output model. The water requirement per hectare for different crops in different world regions are obtained from Hoekstra and Chapagain's studies (2002, 2008) using data originally provided by FAO. Crop areas and livestock data for the UK are collected from ONS (statistical yearbook 2000 – 2005). Crop areas and livestock data for the rest of the world region are collected from FAO ProdSTAT website (http://faostat.fao.org).

For the other industrial sectors data is sparse. The ONS Environmental Accounts (2006, 2009, 2010) provide some data for a small number of industrial sectors and for a limited number of years. In order to model this data within the current framework it has to be disaggregated across the 123 sectors; this means that many sectors will have to assume the same direct water consumption per unit of output. In addition, there was not sufficient historical data to make a baseline projection for the reference scenario for all sectors. However, a suitable time series was available for agriculture and this change has been applied to water use in the agricultural sector.

3.3.2 Ecological footprint data

The direct land-use data for the ecological footprint calculation was taken from the NFA as described in section 2.1.2. The allocation of direct land-use to sectors is done separately for each of the land types as follows:

- **Carbon land:** The UK production carbon land footprint for fossil-fuels was assigned to the 123 industrial sectors and the two direct household consumption categories (domestic consumption of fuels and private transport) by using the respective carbon dioxide emissions from UK Environmental Accounts (ONS, 2009).
- **Cropland and grazing land:** The UK production footprints for cropland and grazing land were both assigned completely to the agricultural sector.
- **Built-up land:** The production ecological footprint for built-land includes area for hydro-power and was attributed to industrial and domestic sectors by using real land requirements for non-domestic premises, based on research undertaken by Bruhns et al., 2000, as well as land area occupied by transport infrastructure and domestic buildings (DTLR, 1999).
- **Fishery and forest land:** The production footprints for fishery and forest area were assigned to the fishing and the forestry sector, respectively.

3.3.3 Materials data

For the indicators that could be added into the input-output model both directly and soft-linked, the total mass of each material that was consumed by UK production was required. Ideally, this would be gathered for both the UK and the rest of the world (as was done for emissions) to take into account potentially differing direct intensities in different world regions. However, for the majority of indicators the direct material use data by industrial sector was not available for other world regions, so the material intensity of imported goods was assumed to be the same as domestically produced goods (as discussed in section 2.2 on data limitations). The material intensity was multiplied by the value of imported goods and services to calculate the total quantity of material embedded in imported goods.

The direct material intensity for domestically produced goods was either obtained from a review of literature where this data was sufficiently robust (for example, there is good data relating to material and value flows in the iron and steel sectors for 2004 (Dahlström et al. 2004) or from production sales data.

Production sales data were collected from two different sources; the EU PRODCOM database and the Office of National Statistics PRODCOM website. We used two different database sources and comparable literature to provide a data cross-check wherever possible. The EU PRODCOM was used as the input once it had been compared to the ONS data and shown to be similar. Where the two sources of data did not match, a third source of data was identified and the data closest to this third source was used. Further details about PRODCOM data and how it was used in this report can be found in section 9.2. For this study PRODCOM was the most consistently available dataset, but it is not necessarily the most appropriate or ideal format for this type of modelling. It had to be assumed that production sales of a material were equivalent to the consumption of this material by UK production. Ideally resource use by industrial sector would be collected in the same way that pollutant data is collected, however this is not yet available for the UK. Consequently, the use of PRODCOM data did generate a number of limitations for this study, which are also discussed in section 9.2, and do influence the way in which results should be viewed.

Additional data was required for the soft-linked materials to provide an understanding of the sectoral interactions. This data is inherent in the model for any of the materials that are added directly, but needs to be sourced separately for any that are soft-linked. Information about which sectors consumed the material of interested was sourced from academic literature and reports and where possible a number of sources of data were consulted to improve the robustness of estimates. Global datasets were used where data on UK sources of consumption by end use were unavailable.

A literature review was undertaken to collate data relating to the quantity of each soft-linked material embedded in products imported from the rest of the world. It was assumed that this material was allocated to the same sectors, in the same proportions as material consumed by UK production.

Material data for the UK is provided in Appendix B of this report. It should be noted that the data provided in this appendix does not include the material embedded in imported goods, which was calculated using UK material intensity and is included in results presented in section 6.

4.0 Forecasting changes to baseline data – generating the reference scenario

The economic model used in this study and the environmental data collated provides us with a baseline of the impact of UK consumption for each indicator in 2004. The data for each indicator was either backcast or forecast (depending on the year of availability and trend data) to 2004. The year 2004 was used as the baseline for this study to maintain consistency with the previous 2009 report. In order to quantify the effect of resource efficiency strategies over time we need to forecast how the economic and environmental data may change – creating a baseline 'reference scenario' with which to compare all other strategies. The impact of the resource efficiency strategies will be measured as a change from this reference scenario.

4.1.1 Baseline economic projections

The economic data projection for the reference scenario was the same as used for the 2009 report. The forecast included changes to the overall structure of the economy and total output (or final demand). This provided new estimates for output from each sector in 2010, 2015 and 2020. Economic output figures for 2010 include estimates of the impact of the global recession on the UK economy. It should be noted that this forecast is based on the current production structure and will not take into account future changes in technology, such as increases in production of hybrid electric vehicles as a result of advances in rechargeable battery technologies.

4.1.2 Baseline environmental intensity projections

In the 2009 report, historical GHG emissions and output estimates were used to project potential future GHG emissions intensity. For this report, an equivalent consistent historical time series was available for the direct ecological footprint data and for some water data sectors, but not for the materials indicators. Consequently the baseline projection of the environmental intensity for the reference scenario is slightly different for each indicator. The approaches used for each indicator are described in more detail below.

Water abstraction

Due to limited data availability for industrial sectors only water use intensity for the agriculture sector was changed in the reference case, using a historical time series of data back to 1999 (ONS, Chapagain and Hoekstra 2003, Hoekstra and Chapagain 2008 and Hoekstra and Hung 2002). This resulted in a cumulative 30% reduction in water use intensity for agriculture from 2004 to 2020. All other industrial sectors were assumed to maintain constant water use intensity up to 2020.

Ecological footprint

The direct land use forecast was generated as part of the NFA for the UK back to the 1960s. The majority of land types applied a straight line projection of continuing trends, but any tending towards zero used a growth trend. Cropland, grazing land and fishing were projected to decrease, where as forest land, carbon land and built land were projected to increase in line with historical trends. In total, this resulted in a projected increase of 6.6% in land use intensity between 2004 and 2020.

Materials

Due to a lack of consistent time series data for materials no change in material intensity was assumed. This means that the direct material intensity per unit of output by sector remains constant in the reference scenario; only the production structure and economic output data change.

5.0 Scenario method and description

The way in which future changes in production and consumption could affect material use, water use and the ecological footprint in the UK are explored using a number of different resource efficiency strategies up to 2020. These strategies are based on a set of assumptions and give an indication of what could happen in the future under those conditions. The strategies are collectively described in this report as a quick win scenario, contrasted against a reference scenario (see section 4). The strategies are not predictive; they describe futures that could be, rather than will be. Our ability to project the future is highly constrained and scenario analysis has been developed as a means of exploring alternative futures (Mander et al., 2008).

The strategies for this analysis are the same as the 2009 report. Using the same strategies means that the impact of the measures taken to reduce GHG emissions can be explored for other indicators, considering the potential co-benefits or possible areas of conflict. The strategies are split into production strategies and consumption strategies, with seven strategies covering resource efficient production supply and six resource sufficient consumption strategies.

5.1 Scenario categories

In the 2009 report the strategies were categorised into three different levels of intervention, from actions that were thought to be quick wins – easily implemented with current infrastructure and resources, to those that would need to overcome significant investment, technological or cultural barriers. **This report considers the impact of the quick wins scenario only.**

The resource efficiency strategies under this scenario were first developed using a participatory approach based on expert input on 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 as part of the 2009 report.

5.1.1 Resource efficient production strategies

The quick win measures for the supply strategies are summarised in Figure 3. A full description of the underlying assumptions and supporting evidence is provided in the 2009 report. Quick win production measures were applied to production in the UK, not to imported goods, since the UK does not have control over production overseas.

Figure 3 Resource efficient production strategies

Lean production	Reduced material inputs into production processes through the design of lighter and leaner products	Material requirement to produce the same good is 15% less in 2020
Material substitution	Substitution of highly carbon intensive materials for low carbon intensive materials	10% of carbon intensive materials used to make goods are replaced with the least carbon intensive material by 2020
Waste reduction	A reduction in waste at the production stage that directly leads to a reduction in material requirements	15% of the raw materials from industry and commerce ending up in the waste stream are taken out of the economy by 2020
Re-direction of landfill materials	Diversion of waste from landfill to recycling	15% of the raw materials from industry and commerce ending up in landfill are recycled and put back into production by 2020
Dematerialisation of the service sectors	Improving the efficiency of product use in the service sector through extending the lifetime of products, reducing edible food waste and eradicating junk mail	A third of discard rate is reduced for the different product groups, edible food waste is halved and junk mail is eradicated by 2020
Strategies for sustainable building	Improving efficiency by introducing modern methods of construction such as modular design and off site construction	2% of the construction market is met by modular building design by 2020
Efficient use of existing infrastructure	Reduce material inputs into construction through replacing new build with retrofit	Retrofitting 20% of housing deemed for demolition and vacant properties offsets the need for rebuilding by 2020

5.1.2 Resource sufficient consumption strategies

The quick win measures for the consumption strategies are summarised in figure 4. A full description is provided in the 2009 report.

Figure 4 Resource sufficient consumption strategies

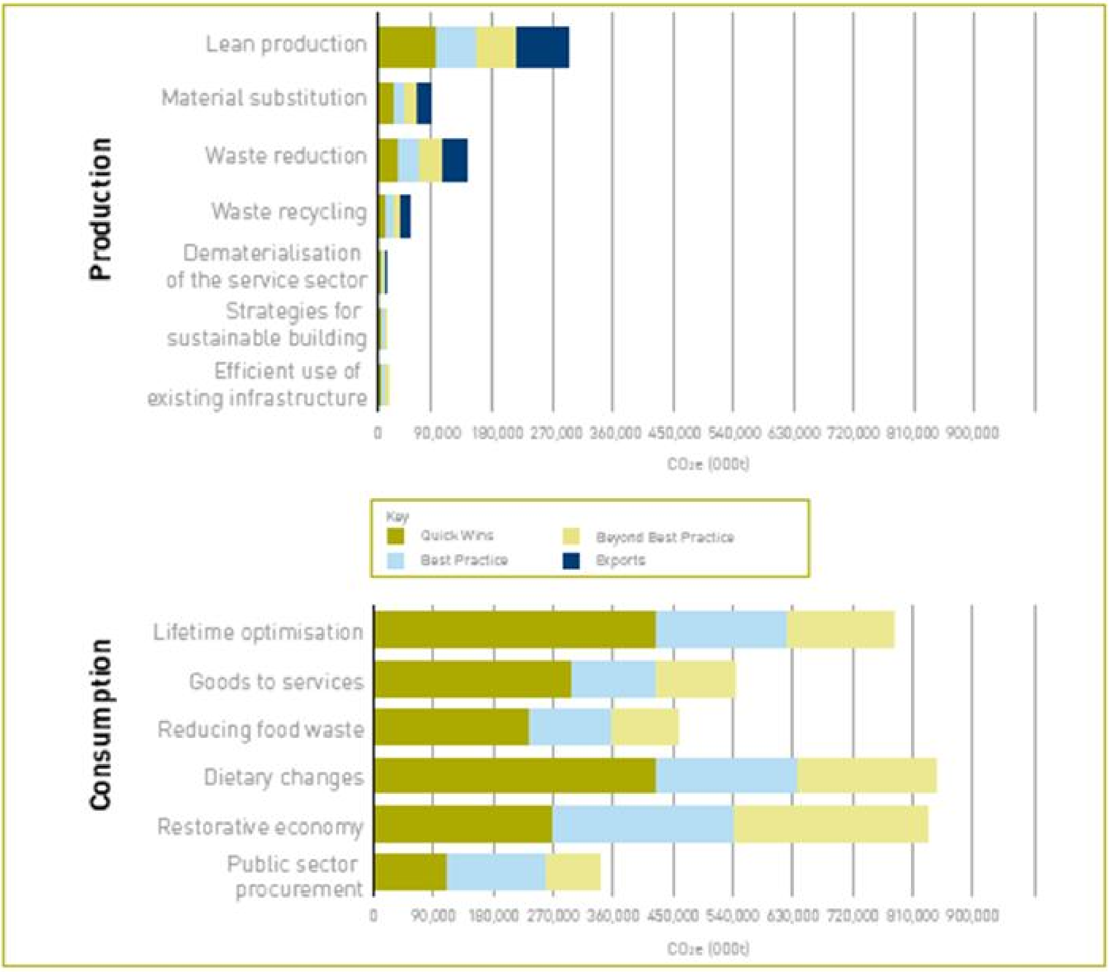
Lifetime optimisation	Ensuring that products are used by households for their full useful life	The discard rate for different product groups is reduced by a third by 2020
Shift from goods to services	Reduction in ownership of goods, delivered instead by the service sectors	A shift in the market to service provision varies for selected goods of between five and 20%
Reducing food waste	Reduction in edible food waste within households	Households halve edible food waste between 2010 and 2020
Dietary changes	Reduction in animal-based food products through the introduction of more healthy diets	Meat and dairy consumption is reduced by 25% by 2020
Restorative economy	Extending the life of products by improving product durability	10% reduction in expenditure on selected products by 2020
Public Sector procurement efficiency	Government lead the way in sustainable procurement	The public sector reduces the impact of the goods they purchase by 5% per year by 2020

5.2 Setting the scene: How GHG emissions changed in the previous study

Figure 5 shows the results for GHG emissions reduction from the 2009 report. There are a number of high-level conclusions for the quick-win strategies that should be noted for comparison purposes in this study:

- Overall, the consumption or resource sufficiency strategies delivered much greater decreases in GHG emissions than the production based strategies.
- Life time optimisation and dietary changes demonstrated the largest emissions savings over the quick win time period (up to 2020).
- Lean production made the greatest impact to GHG emissions on the production side. 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.

Figure 5 Change in total GHG emissions from consumption and production strategies in the 2009 report



5.3 Scenario application and limitations

The quick win strategies represent only the changes that could be made under current cultural, technological and infrastructural bounds. They do not explore a marked change in technology – such as a major consumer shift to the use of hybrid or plug-in electric vehicles, for example. In part this restriction is due to the constraints of the quick win assumptions, but in addition it is limited by the capabilities of the model to alter industrial sectors. This is a common problem with any model based on existing structures – the current UK input-output framework describes how the economy functions at the present time, it does not include future unknown or undeveloped technologies that are not part of the existing system. Over time, the structure of the economy will change as newer technologies establish themselves as sectors and the classification system will be changed to reflect this. However, until that point the industrial sectors remain the same across the lifetime of the scenario.

Whilst the basis of the modelling is a limitation of the strategies to some extent, it is also a benefit as it constrains the strategies to what is achievable under the current system. It also has the capacity to look at other options for delivering change, particularly consumption strategies that may be easier and cheaper to implement than technological change.

The strategies modelled in this report change exactly the same variables to the same extent as the 2009 report for emissions. New strategies were not added, and the focus of strategies was not changed. Consequently, the results may not present what might be intuitively expected for that indicator. Instead the results can demonstrate which of the emissions strategies are most effective for other indicators.

A key advantage of this methodology is that this will demonstrate whether there are any co-benefits or areas of conflict across all of the indicators, something that has not been assessed to date. An obvious extension to this work would be to devise new strategies to explore resource specific issues (e.g. focusing on products which use a certain material) and then to evaluate the GHG impacts of these.

5.3.1 How the new indicators will change under the strategies

How each of the indicators change by the different strategies is dependent on four factors:

- which sectors are altered in the strategy and the links they have to the indicator;
- the number of sectors altered;
- the scale of the alteration; and
- the intervention point of the strategy (intermediate demand between sectors, final demand or direct indicator intensity).

The intervention point of the strategy depends on whether it is a production change or a consumption change. The input-output model calculates the indirect or embedded indicator intensity of different products and services and any supply-side strategies change this intensity. Consumption strategies change the expenditure on different product groups, which is multiplied by the indirect indicator intensity of products to generate total impact.

In the 2009 report this process was completed for GHG emissions. The strategies changed the total GHG emissions in one of two ways; by either changing the intensity per product or changing the expenditure on that product (see section 3.2.1). Any change to the intermediate demand or direct indicator intensity affected the indirect emissions intensity factors calculated by the model and any change to final demand altered the expenditure on those products. The system is exactly the same in this report, but instead of GHG emissions intensity it is abstracted water, ecological footprint or material intensity; so wood or water embedded in the supply chain of products for example.

The changes to the indicators are only a reflection of the changes that are made in the strategies. The purpose of strategies such as these is to demonstrate the answer to “what if” questions: they are not designed to forecast the growth in demand for materials or to predict future resource scarcity or price fluctuations. This study will test the indicator expansion capabilities of the model, and the appropriateness of doing so.

6.0 Quick Win Results

6.1 Blue water consumption

6.1.1 Reference scenario

The results for the reference scenario and percentage impact associated with spending on imported products are shown in table 3. The reference scenario increases by 4.2% between 2010 and 2020; this demonstrates the impact of the two variables that change in the reference scenario:

1. Changes to the economic data: a steady increase in demand for products of around 2.2% per year between 2010 and 2020 and small changes to the structure of the economy.
2. A decrease in water use intensity of the agricultural sector of approximately 1.8% per year.

The change in water use intensity is equivalent to the changes in direct GHG emissions intensity modelled in the 2009 report. For this study, only the agricultural sector water intensity was altered in the reference scenario, due to lack of data for the other sectors. However, as the agricultural sector is the principal water consumer, any changes to the water intensity of this sector will be evident in the totals.

Despite not being able to model different indicator intensities in other countries for this study, the economic data used still demonstrates the growing demand from imports. An increasing percentage of impact is attributed to this (see Table 4). Further investigation and an improvement in data availability would provide a greater insight into the potential impacts of this trend across all indicators.

Table 4 Reference and cumulative scenario results for water

Abstracted Water	**2010**	**2015**	**2020**	**Percentage change 2010-2020**
Total reference scenario (million m^3)	30,406	31,076	31,682	4.2
Percentage from Imports in reference scenario (%)	29	33	34	

6.1.2 The benefits of the resource efficiency strategies

The overall cumulative impact of the resource efficiency strategies was to reduce water use by 5.8% relative to the reference scenario for 2020. The results by scenario are shown in Figure 6 and Figure 7, split by resource efficiency and sufficiency strategies.

Figure 6 Change in total water use from resource efficiency (production) strategies

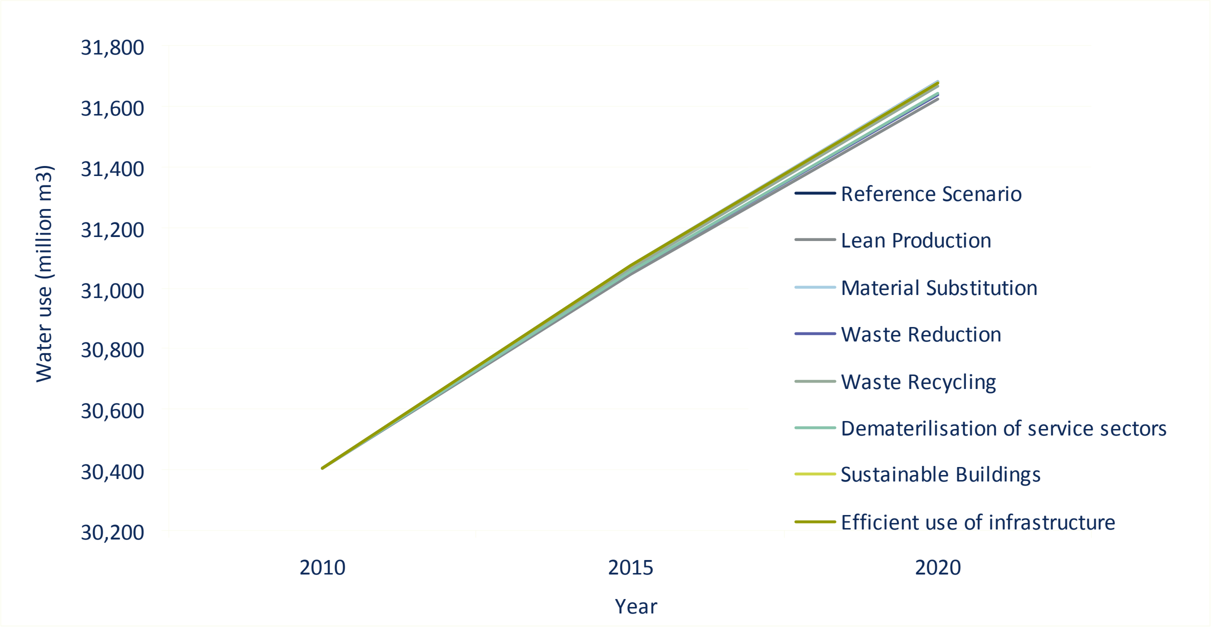
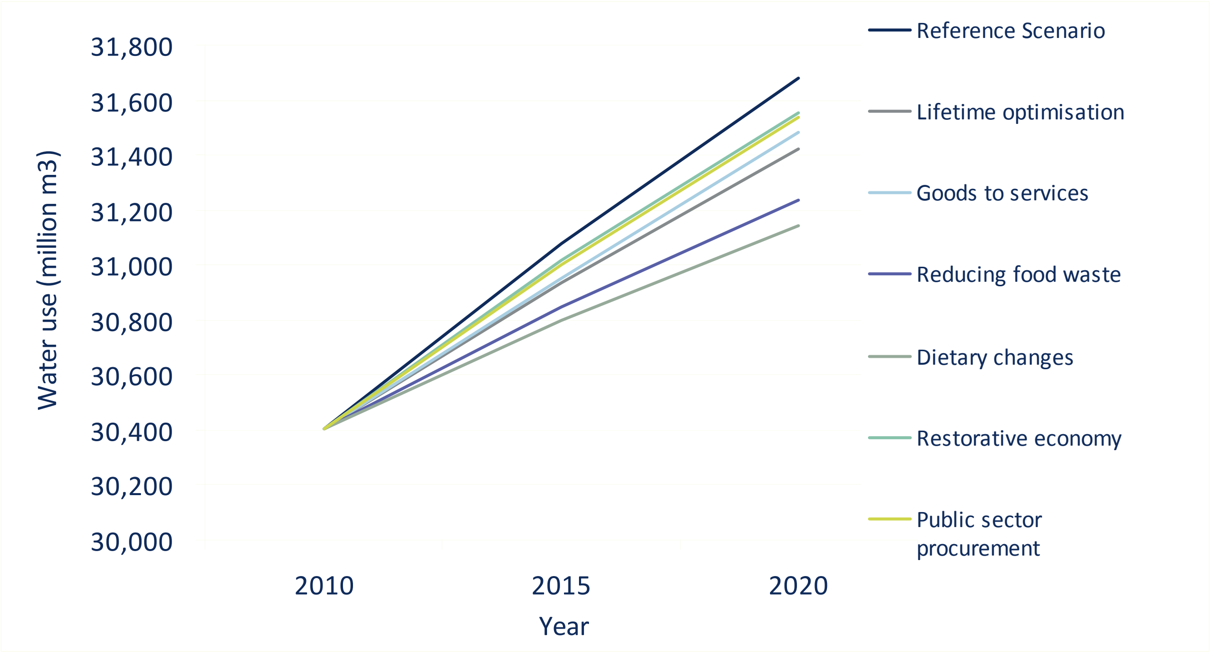


Figure 7 Change in total water use from resource sufficiency (consumption) strategies

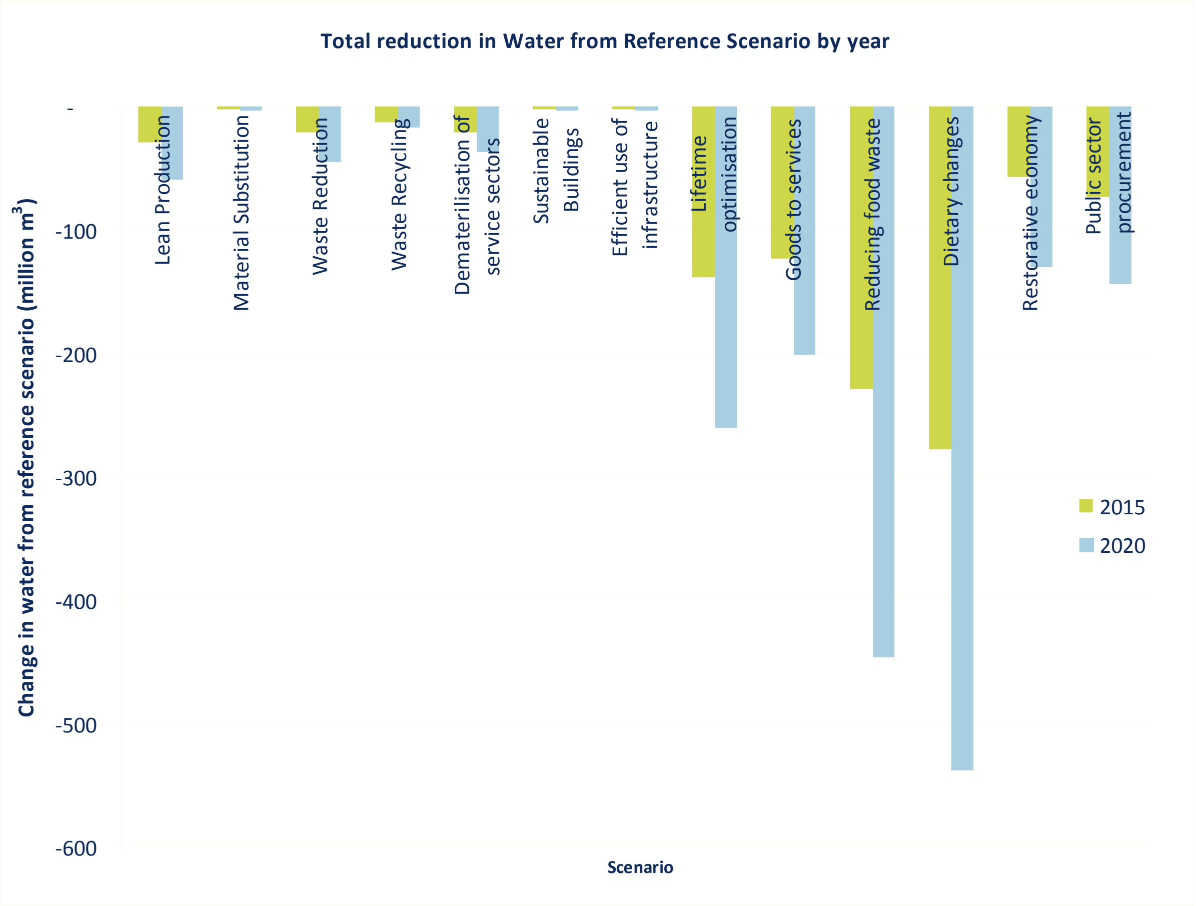


The most effective strategies for reducing abstracted water were dietary change and reducing food waste, generating a 5.1% and 4.8% reduction in water respectively between 2010 and 2020. The main reason for this is that the sectors altered in these strategies are associated with agriculture, and agriculture has the greatest direct water intensity of all the sectors.

The lifetime optimisation strategy is the next most effective strategy. The other strategies generated lower reductions across a smaller number of sectors.

Figure 8 illustrates that the consumption strategies had a greater impact on water use, making up over 90% of the total reduction, compared to the production strategies which only accounted for around 10%. This finding is in line with the results from the 2009 report for emissions, which also found that consumption strategies yielded higher reductions.

Figure 8 Total change from reference scenario in water use by resource efficiency strategy



6.2 Ecological footprint

6.2.1 Reference scenario

All of the following results for the ecological footprint are separated out into the total land footprint and the carbon land footprint. The carbon land footprint makes up over 65% of the total ecological footprint, which demonstrates the dominant impact that the release of carbon emissions has on the demand for bio-productive land. The results of the reference scenario analysis for the ecological footprint are presented in Table 5. This shows the projected change in ecological footprint if no resource efficiency strategies were implemented, with just the underlying economic and environmental intensity projections (see section 4.1.2 for exact assumptions).

Table 5 Reference scenario results for the ecological footprint

	Ecological footprint (k gha)			
	2010	**2015**	**2020**	**Percentage change 2010-2020**
Fishing	5,885	5,927	5,790	-1.6%
Forest	4,667	5,161	5,658	21.2%
Grazing land	10,842	11,487	11,735	8.2%
Built land	7,565	8,573	9,720	28.5%
Carbon land	135,159	147,997	158,763	17.5%
Cropland	40,342	42,183	42,566	5.5%
Total land footprint	***69,301***	***73,331***	***75,470***	***9%***
Total carbon land footprint	***135,159***	***147,997***	***158,763***	***17%***

The ecological footprint reference scenario can be separated into the impact associated with domestic consumption of UK goods and consumption satisfied by imports for each of the land types for each time period. The percentage of the total ecological footprint impact associated with imports is shown in Figure 9. How the impact of imports changes across land types is dependent on the import expenditure on different products and how those products relate to the land types. For example, the majority of products have a carbon land impact and the demand for imports for most products is also increasing. As a result the percentage of carbon land impact from consumption satisfied by imports is growing.

Figure 9 Ecological footprint associated with imports by land type 2010-2020

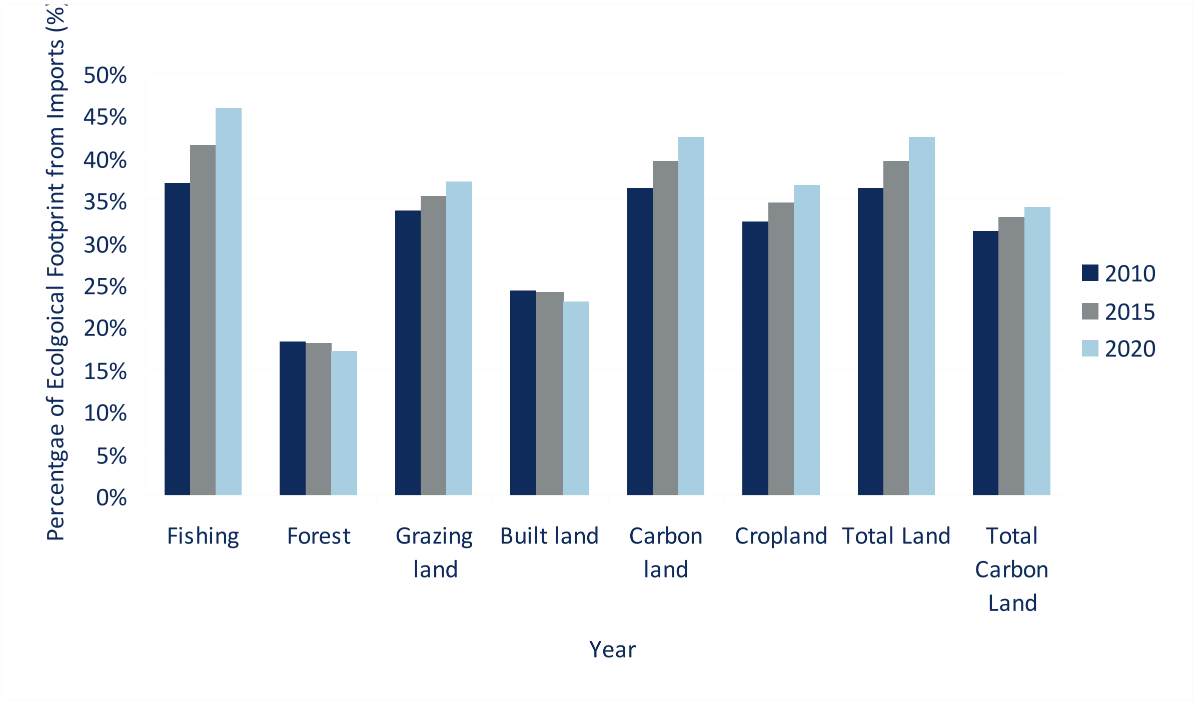
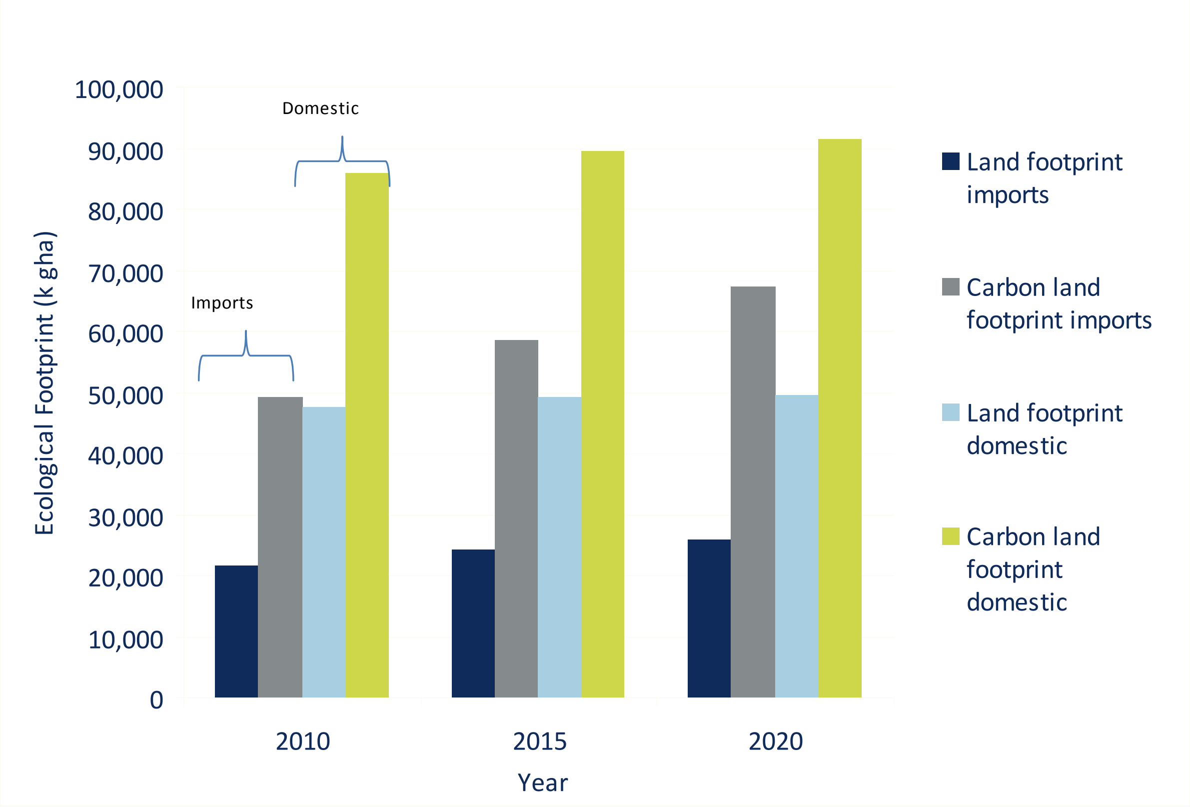


Figure 10 displays the ecological footprint reference scenario split by total land footprint and carbon land footprint and split by domestic and import impacts. This shows that the carbon land footprint associated with imports is nearly the same size as the land footprint domestically. This highlights the importance of imports and the dominance of carbon land in the total ecological footprint.

Figure 10 Ecological footprint from domestic and import consumption in the reference scenario, by land type, 2010-2020



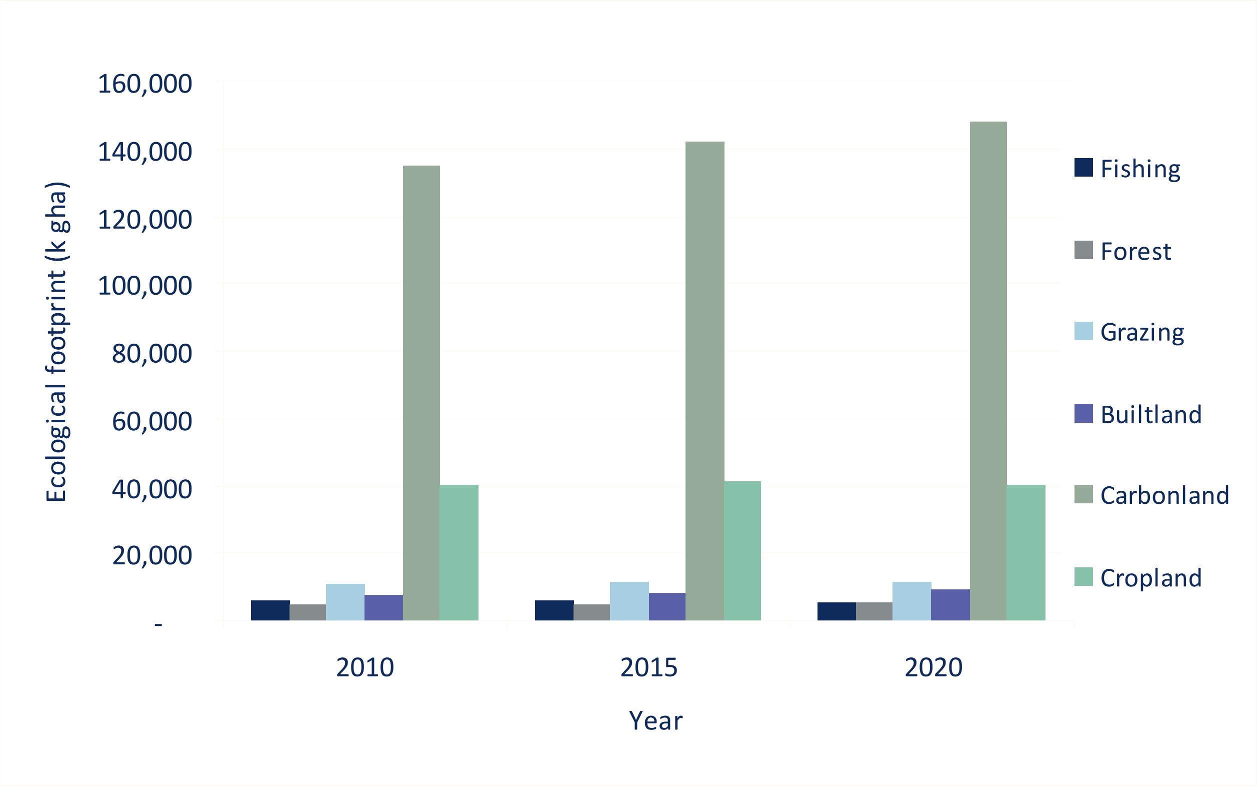
6.2.2 *The benefits of resource efficiency strategies*

This section describes the results from the application of the different resource efficiency and sufficiency strategies to the ecological footprint reference scenario. The summary in Table 6 demonstrates the cumulative impact of all the resource efficiency and sufficiency strategies on both the land footprint and the carbon land footprint. The cumulative impact of the strategies caused a decrease across all land types; however, the decreases were not enough to outweigh the underlying growth trend, resulting in an overall increase in impact despite the application of the different resource efficiency and sufficiency strategies. The new totals for all of the land types following the implementation of all strategies is shown as a cumulative total in Figure 11.

Table 6 Ecological footprint cumulative scenario impact results

Comparison of the reference scenario and cumulative scenario impact	**Percentage change 2010-2020 reference scenario**	**Cumulative percentage change 2010-2020 from all strategies**	**Difference between reference scenario and cumulative strategies by 2020**
Fishing	-2%	-8%	-6%
Forest	21%	12%	-7%
Grazing	8%	3%	-5%
Built land	28%	21%	-6%
Carbon land	17%	9%	-7%
Cropland	6%	0%	-5%
Total land footprint	***9%***	***3%***	***-5%***
Total carbon land footprint	***17%***	***9%***	***-7%***

Figure 11 Change in total ecological footprint by land type from all strategies cumulatively 2010-2020



The effect of the strategies did vary similarly to abstracted water, with the majority of the reduction in impact associated with consumption strategies. The production strategies were more significant for ecological footprint than water, making up just under 20% of the reduction, compared to 10% for water.

Figure 13 Percentage contribution from each strategy to the reduction in total land and carbon land footprints

Figure 12 shows how the different strategies contribute to the overall reductions in ecological footprint and Figure 13 breaks this down into land footprint and carbon footprint. Lifetime optimisation and goods to services contribute the most to the carbon land footprint, whilst reducing food waste and dietary changes contribute most to the land footprint reductions. Lean production was the most effective production strategy. The changes to the ecological footprint are similar to those for water use and GHG emissions.

The contribution from each strategy to the reduction in 2015 and 2020 is displayed in Figure 14. In terms of totals, the goods to services strategy showed the largest reduction in 2015. Further to this, it has been possible to break down the contribution to each strategy by industrial sector. This has allowed the strategies to be ranked by the number of sectors affected. For example, the lean production strategy gave the greatest reduction from the reference scenario by 2020 in 63 sectors, compared to dietary changes that only gave the greatest reduction in five sectors. This analysis is provided in Table 7.

Figure 12 Percentage contribution from each strategy to the reduction in total ecological footprint

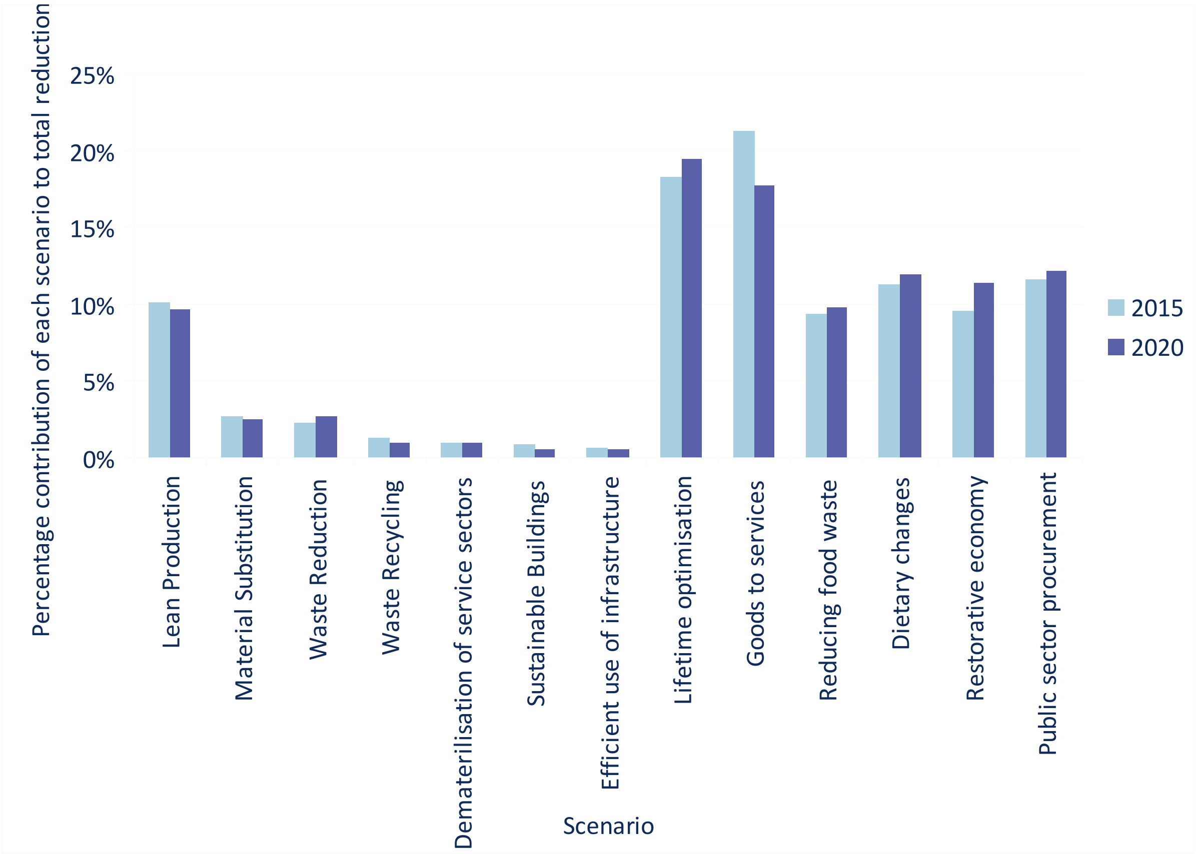


Figure 13 Percentage contribution from each strategy to the reduction in total land and carbon land footprints

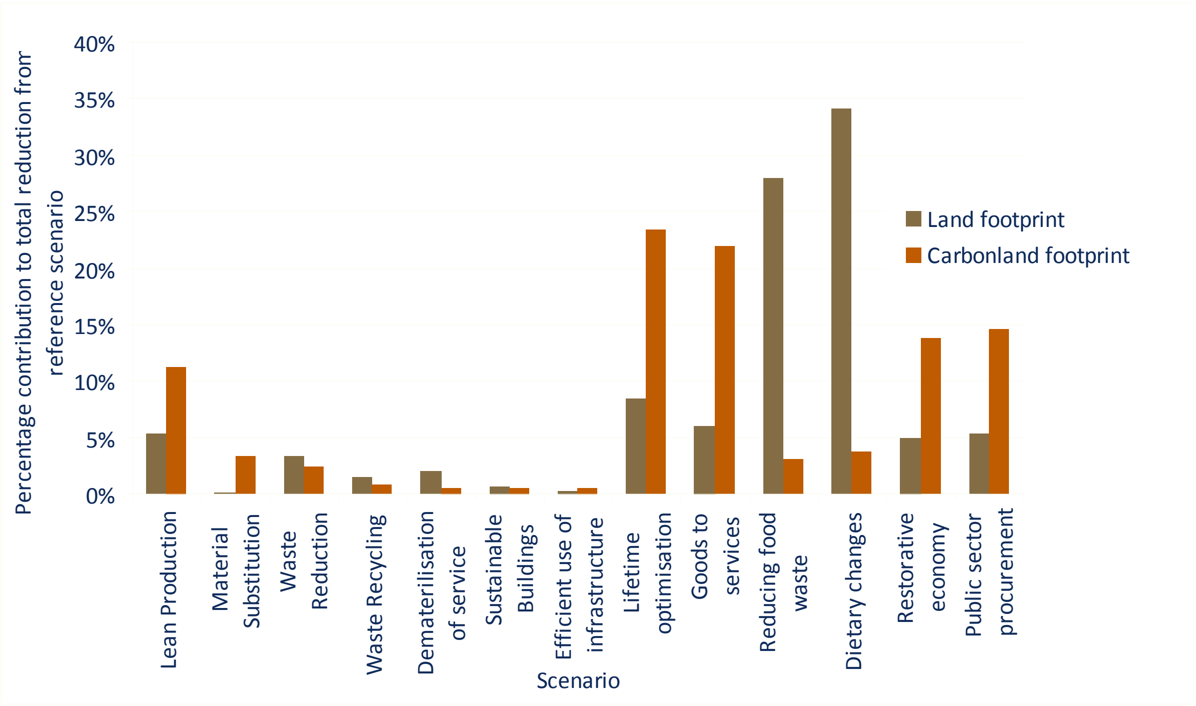


Figure 14 Total reduction in ecological footprint from reference scenario by year

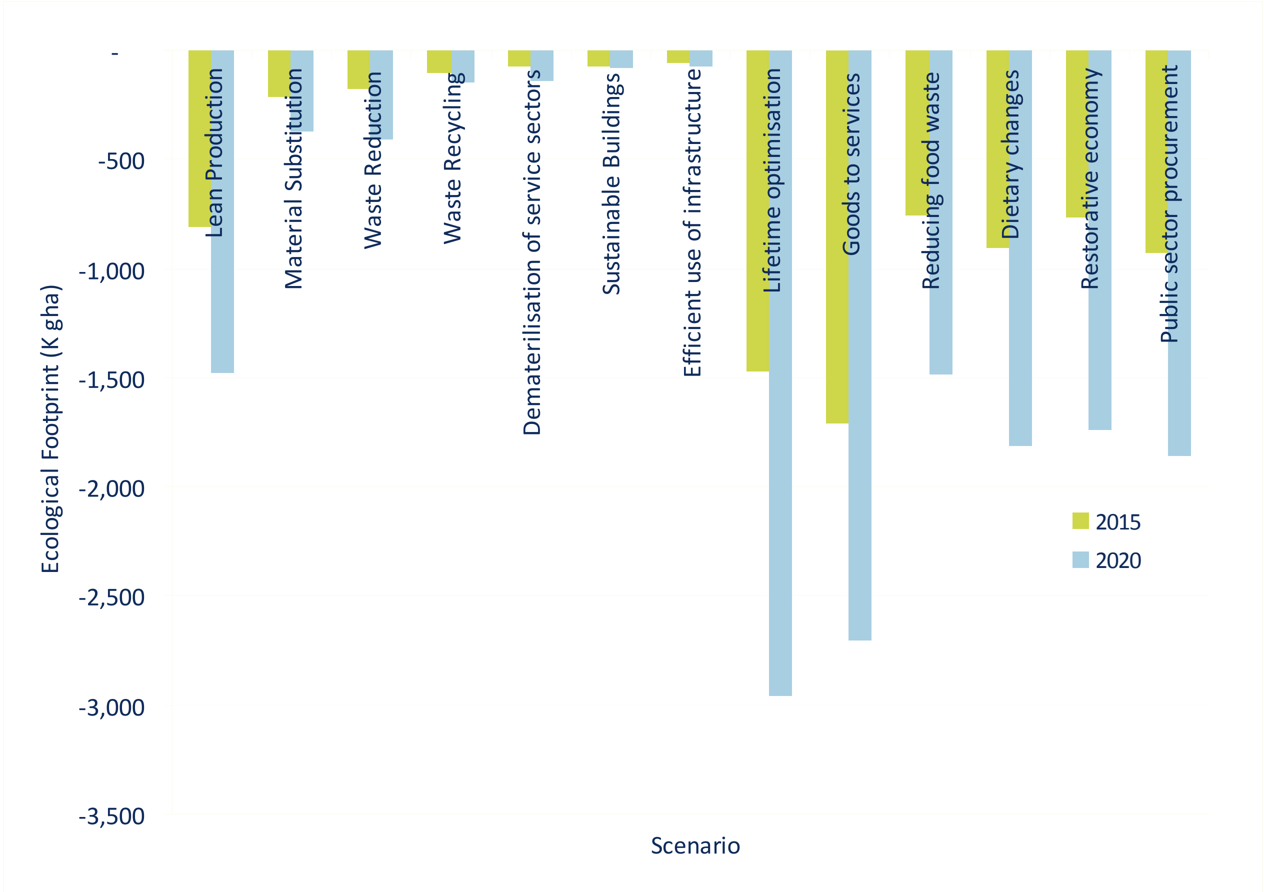


Table 7 Ecological footprint cumulative scenario impact results

	Number of sectors where the Specified strategy gave greatest reduction from reference scenario		Total change in Ecological footprint from reference scenario (k gha)	
Strategy name	**2015**	**2020**	**2015**	**2020**
Lean Production	60	63	- 808	- 1,477
Goods to services	12	13	- 1,469	- 2,957
Lifetime optimisation	10	11	- 181	- 405
Material Substitution	10	9	- 1,708	- 2,705
Waste Reduction	9	8	- 212	- 370
Reducing food waste	7	5	- 929	- 1,857
Public sector procurement	6	5	- 755	- 1,484
Dietary changes	4	5	- 903	- 1,811
Dematerialisation of service sectors	3	2	- 76	- 140
Restorative economy	0	0	- 105	- 152
Waste Recycling	0	0	- 73	- 85
Sustainable Buildings	0	0	- 56	- 78
Efficient use of infrastructure	0	0	- 766	- 1,741

6.3 Materials added directly to the model

6.3.1 Reference scenario

In the reference scenario for materials the underlying material intensity per unit of output was kept constant for all materials, due to the lack of historical data available to generate projections. Consequently, the reference scenario shows only the impacts of changes to production structure and changes to overall economic growth (output and demand). This is shown in Table 8.

Table 8 The change in total material impact in the reference scenario

	Total material impact from consumption (domestic and imported) (Kt)			
Indicator	**2010**	**2015**	**2020**	**Percentage change 2010-2020**
Wood	26,219	26,829	27,611	5.3%
Pulp and paper	10,090	10,253	10,333	2.4%
Fertilizers	5,642	6,033	6,241	10.6%
Plastic and synthetic resins	4,760	5,333	5,775	21.3%
Plastic products	6,380	6,869	7,281	14.1%
Iron and steel	13,169	13,919	14,448	9.7%

The percentage of the total material impact associated with the consumption of imported goods is displayed in Table 9. The material impact associated with consumption of imported products is rising steadily over time for all indicators apart from fertilizers. The underlying assumption of a single region model means that differences in material intensity per unit of output in other regions of the world are not considered. This possible trend for increasing impact associated with imports should be explored further, particularly if materials are found to be sourced from areas where local environmental impacts are high.

Table 9 The percentage of total material impact associated with the consumption of imports

	Percentage of total material impact from imported products		
Indicator	**2010**	**2015**	**2020**
Wood	22.1%	23.9%	24.6%
Pulp paper	44.8%	49.9%	53.4%
Fertilizers	41.9%	37.7%	33.0%
Plastic and synthetic	52.0%	53.6%	53.4%
Plastic product	35.0%	37.5%	38.9%
Basic iron	42.1%	44.9%	47.4%

6.3.2 The benefits of resource efficiency strategies

In this section, the effect of each strategy on all of these material indicators is presented for each material. When analysing the results it is important to note that the strategies have not been designed specifically for the indicator.

The same reduction principles apply to materials, water, and ecological footprint, as outlined in section 5.3.1. Unlike the 2009 report, material substitution has been excluded. This is because the substitution assumption was previously made based on moving to lower carbon intensity materials. If this same assumption was applied to the material indicators they would increase or decrease based on their carbon intensity, rather than a material relevant indicator such as raw material resource intensity or whether material input could be reasonably reduced.

The impact that both the production and consumption strategies will have on the different indicators is dependent on whether the sector altered in the scenario buys a lot of the product relevant to the material of interest. For example, the agricultural sector spends 9% of its total intermediate demand on fertilizers and 0.4% on forestry products.

Table 10 shows the sectors that spend a high proportion of their total intermediate demand on each of the materials. Each column shows the top five sectors, for example, 14% of the soft drinks sector's total intermediate demand is for plastic products, 20% of the furniture sector's total intermediate demand is for wood and wood products. If a strategy changes the expenditure of sectors that buy a lot of the materials of interest, then it is likely to have a larger impact on that total material impact. This is why lean production is shown to be so effective for many of the materials because it directly reduces expenditure on a variety of products which contain the materials of interest.

Table 10 Percentage of intermediate demand spent on materials of interest

Percentage of the named sector's intermediate demand expenditure on each of the product groups of interest											
Wood & wood products		**Pulp, paper & paperboard**		**Fertilisers**		**Plastics & synthetic resins etc.**		**Plastic products**		**Iron & steel**	
Wood products	49%	Wood products	2%	Agriculture	9%	Plastics & synthetics	19%	Soft drinks	14%	Iron & steel	31%
Pulp and paper	4%	Pulp and paper	34%	Forestry	0%	Paints	14%	Footwear	8%	Structural metal products	35%
Furniture	20%	Paper & paperboard	50%	Fertilisers	27%	Man-made fibres	17%	Soap & toiletries	14%	Metal forging, pressing etc.	22%
Sports goods & toys	8%	Printing & publishing	12%	Membership organisations	0%	Rubber products	11%	Plastic products	21%	Cutlery, tools etc.	17%
Construction	3%	Articles of concrete, stone etc.	1%	Recreational services	1%	Plastic products	31%	Sports goods & toys	14%	Other metal products	32%

Individual strategy results

The following six graphs (Figures 15-20) show the total material avoided by indicator for each strategy.

Although all of the strategies reduced material consumption relative to the reference scenario, for many materials the absolute level of use projected in 2020 is still higher than in 2010. The only exceptions to this are wood, where lean production causes an overall reduction in consumption, and iron and steel where lean production, lifetime optimisation and goods to services strategies all resulted in a reduction by 2020.

Figure 15 Total reduction in wood from reference scenario by year

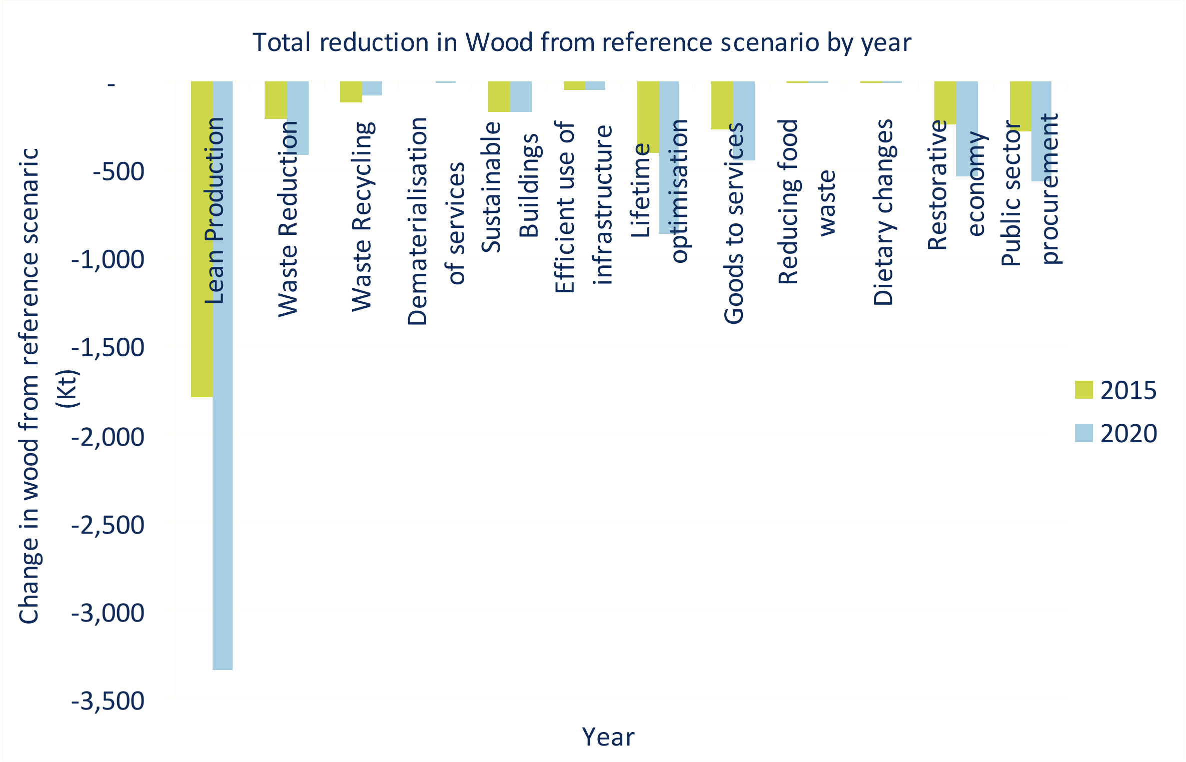


Figure 16 Total reduction in pulp and paper from reference scenario by year

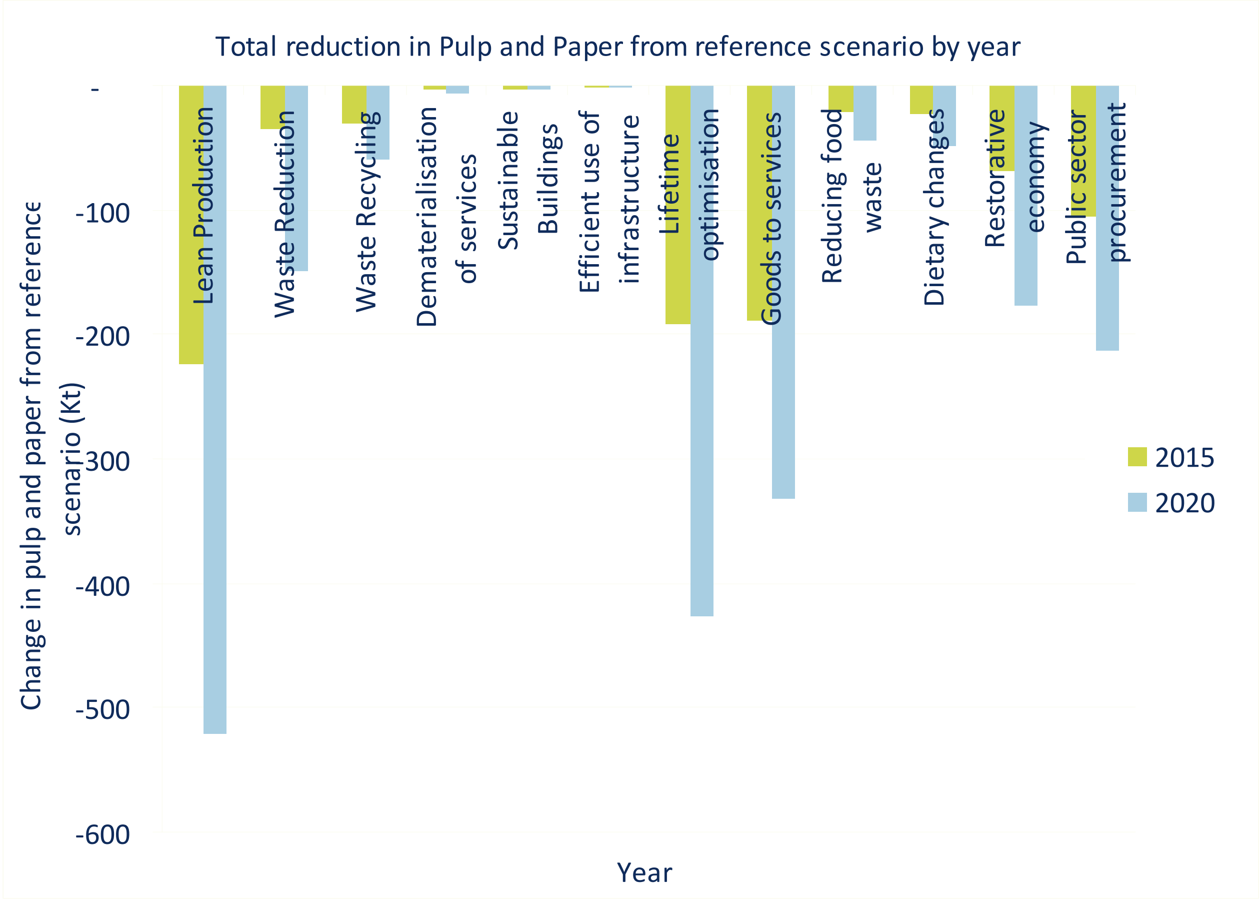


Figure 17 Total reduction fertilizers from reference scenario by year

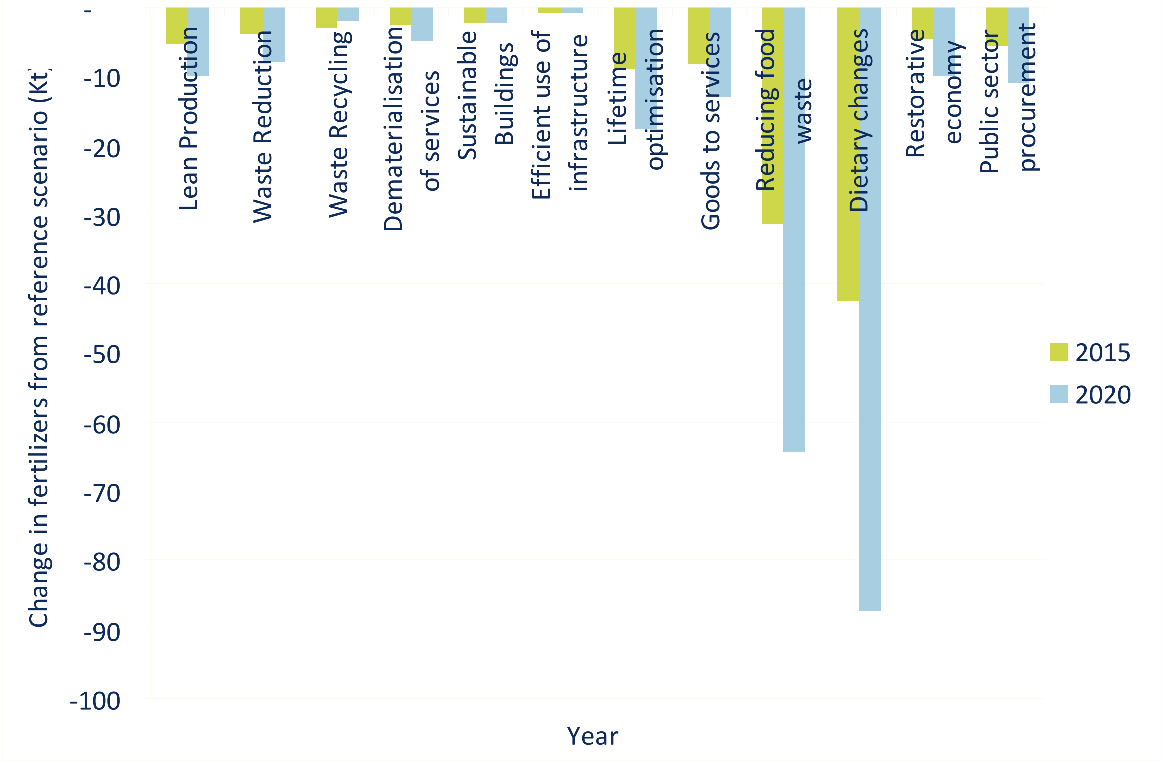


Figure 18 Total reduction in plastics and synthetic resins from reference scenario by year

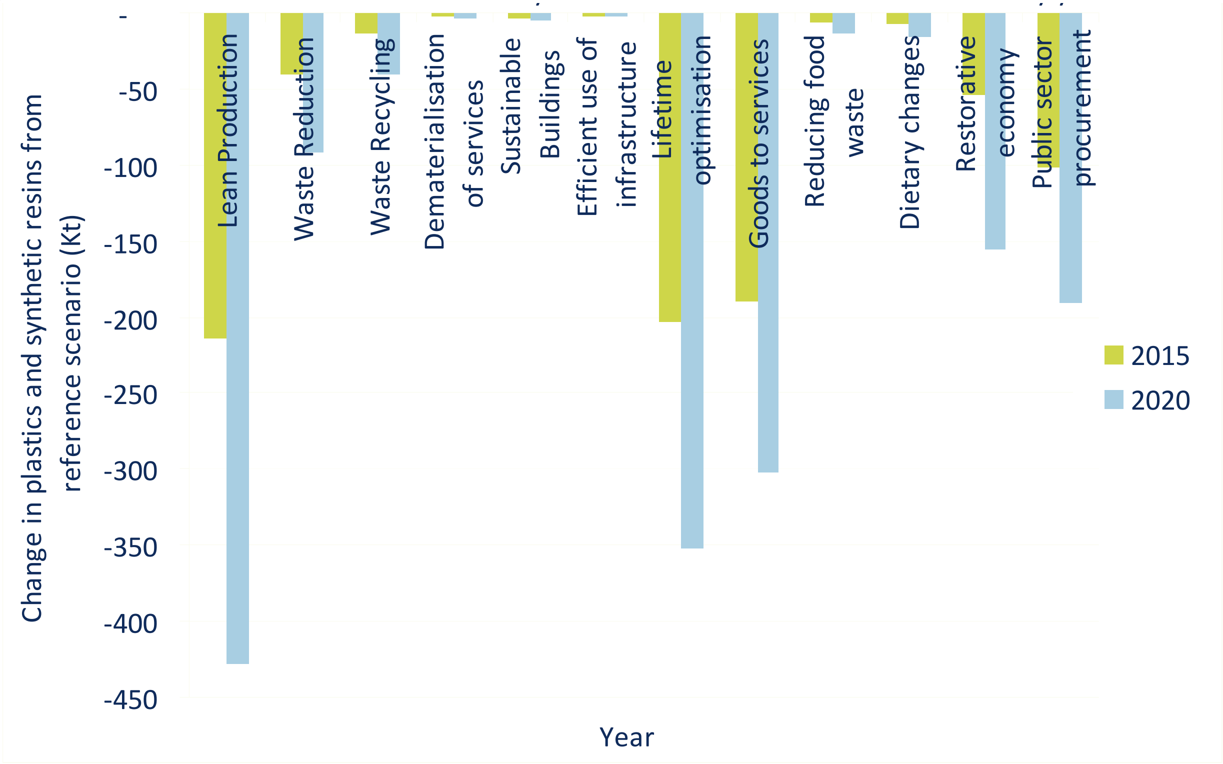


Figure 19 Total reduction in plastic products from reference scenario by year

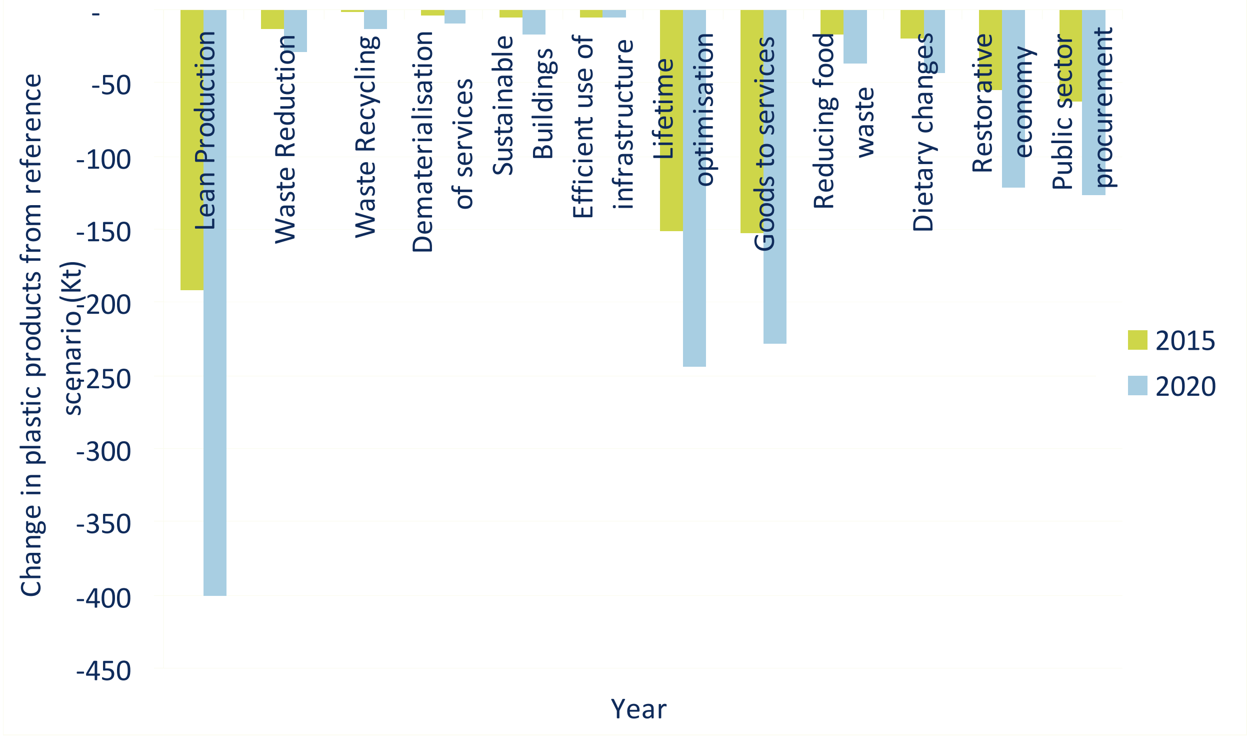


Figure 20 Total reduction in iron and steel from reference scenario by year

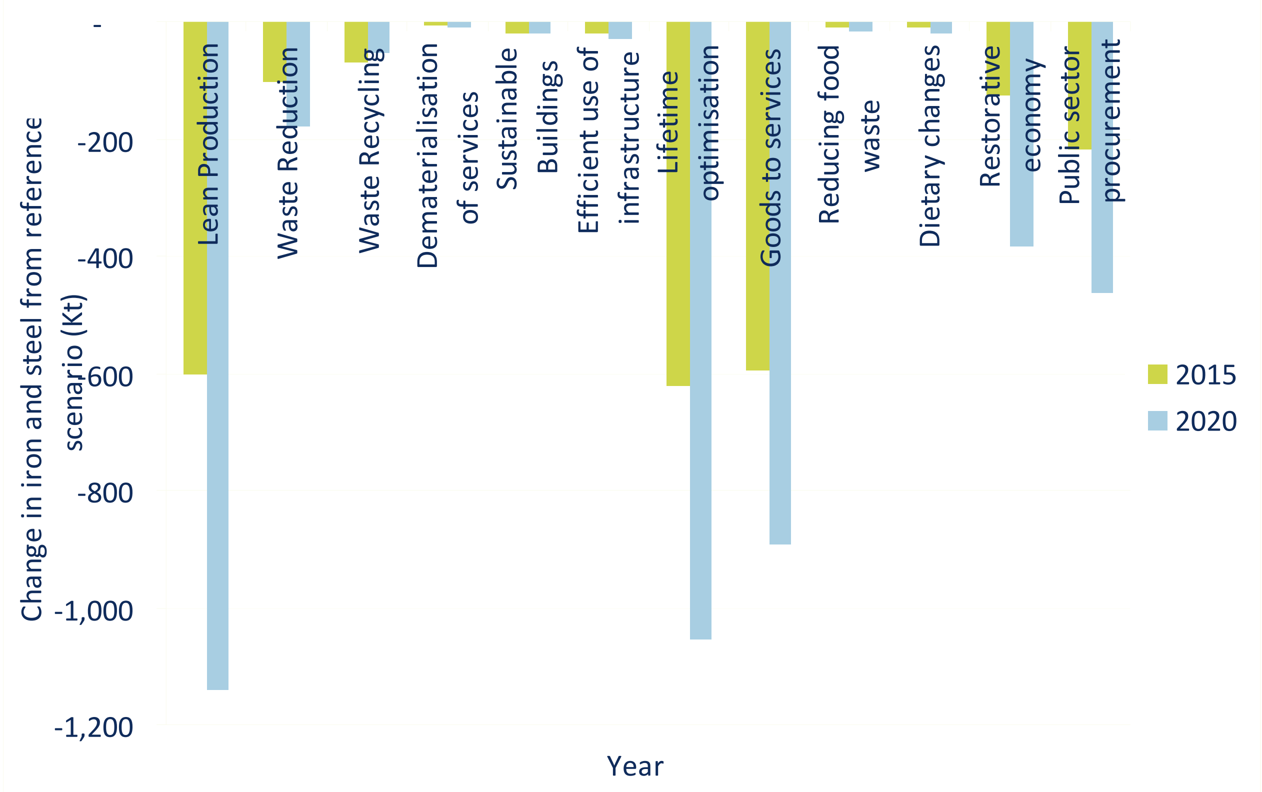


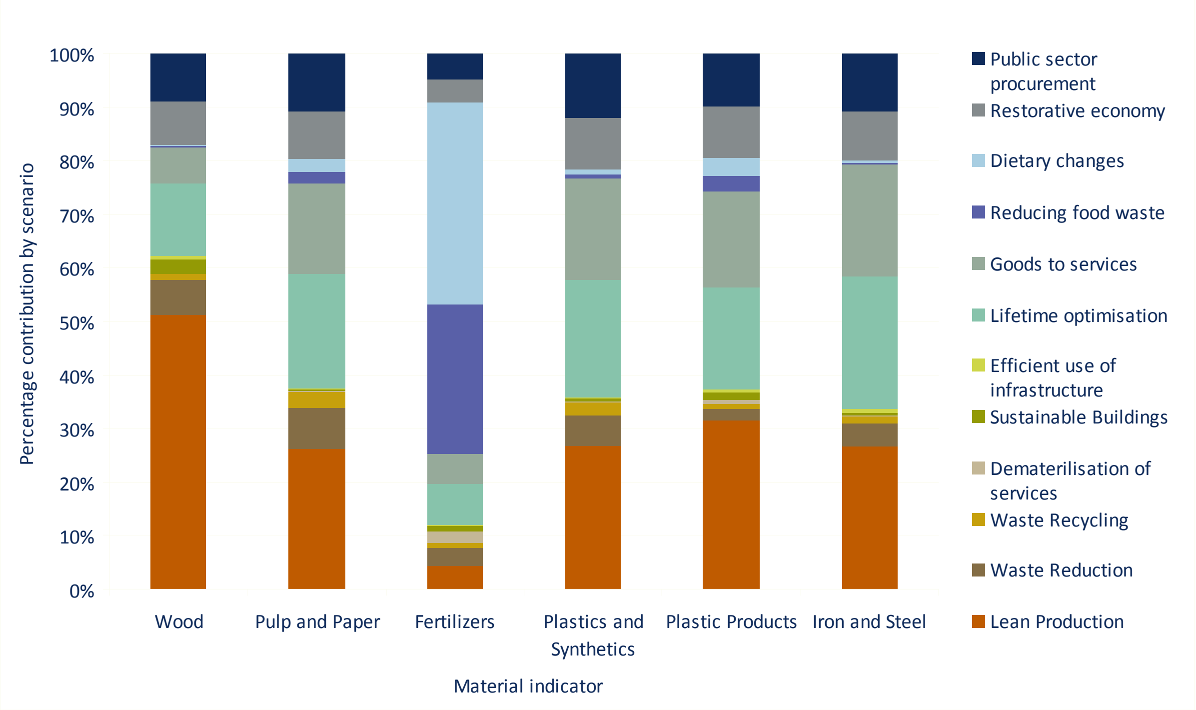
Table 11 summarises the results for all materials and strategies from two perspectives, showing the absolute tonnage reduction and percentage change from the reference scenario by 2020.

Table 11 The total change in material impact from the reference scenario by 2020 and the percentage change between 2010 and 2020 for each strategy.

	Wood		**Pulp and Paper**		**Fertilizers**		**Plastics and Synthetics**		**Plastic Products**		**Iron and Steel**	
	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020
Reference scenario	~	5%	~	2%	~	11%	~	21%	~	14%	~	10%
Lean production	-3,333	-7%	-521	-3%	-10	10%	-428	12%	-400	8%	-1,140	1%
Waste reduction	-412	4%	-150	1%	-8	10%	-91	19%	-28	14%	-179	8%
Waste recycling	-77	5%	-59	2%	-2	11%	-41	20%	-13	14%	-52	9%
Dematerialisation of service sectors	-5	5%	-6	2%	-5	11%	-4	21%	-9	14%	-11	10%
Sustainable buildings	-169	5%	-3	2%	-2	11%	-5	21%	-17	14%	-21	10%
Efficient use of infrastructure	-54	5%	-2	2%	-1	11%	-3	21%	-6	14%	-30	9%
Lifetime optimisation	-862	2%	-426	-2%	-17	10%	-352	14%	-244	10%	-1,056	2%
Goods to services	-443	4%	-332	-1%	-13	10%	-302	15%	-228	11%	-891	3%
Reducing food waste	-13	5%	-45	2%	-64	9%	-13	21%	-37	14%	-18	10%
Dietary changes	-15	5%	-49	2%	-87	9%	-15	21%	-43	13%	-21	10%
Restorative economy	-541	3%	-177	1%	-10	10%	-156	18%	-121	12%	-384	7%
Public sector procurement	-574	3%	-213	0%	-11	10%	-191	17%	-126	12%	-462	6%
Cumulative reduction	***-6,082***	***-18%***	***-1,855***	***-16%***	***-227***	***7%***	***-1,452***	***-9%***	***-1,195***	***-5%***	***-3,843***	***-19%***

The impact of each strategy varies across indicators. For some such as fertilizers the food based strategies are very important, for others it is lifetime optimisation or goods to services. For most of the indicators lean production features highly. Figure 21 shows in percentage terms the contribution of each strategy to the reductions across the indicators.

Figure 21 Percentage contribution of strategies to material reduction



For a number of the indicators the cumulative percentage reduction for all strategies appears quite high, with a 19% reduction in iron and steel for example. Whilst this reduction seems quite considerable, it is on average a 1.5% reduction from the reference scenario by 2020 for each of the 13 strategies, less than 0.15% per year per scenario over the 10 year time period. In reality, the spread of reductions are skewed with some strategies generating substantial reductions and others very little as demonstrated in the graph above.

One of the main limitations of the production strategies is their suitability across all indicators; for some materials a reduction in expenditure on products may not equate to a similar reduction in the material input requirement. A natural extension to this work would be to explore further production strategies which are specific to each indicator and test the assumptions against indicator evidence.

6.3.3 Commentary on lifetime optimisation and goods to services strategies

Lifetime optimisation and goods to services strategies were the most effective consumption strategies for all of the indicators apart from fertilizers (where dietary changes and reducing food waste were most effective). The discussion below provides insights into how they are linked to materials and explanation for why the strategies have the impact that they do. Each strategy is taken in turn with a summary of the original assumptions of two strategies presented first. These assumptions are the same as the 2009 report.

Lifetime optimisation

Material goods that have the possibility to be used longer, thus reducing their replacement rate, were identified in the 2009 report, these were: 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 demonstrated that on average 30% of all products thrown away are still working (Cooper, 2004), summarised in Table 12.

Table 12 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**

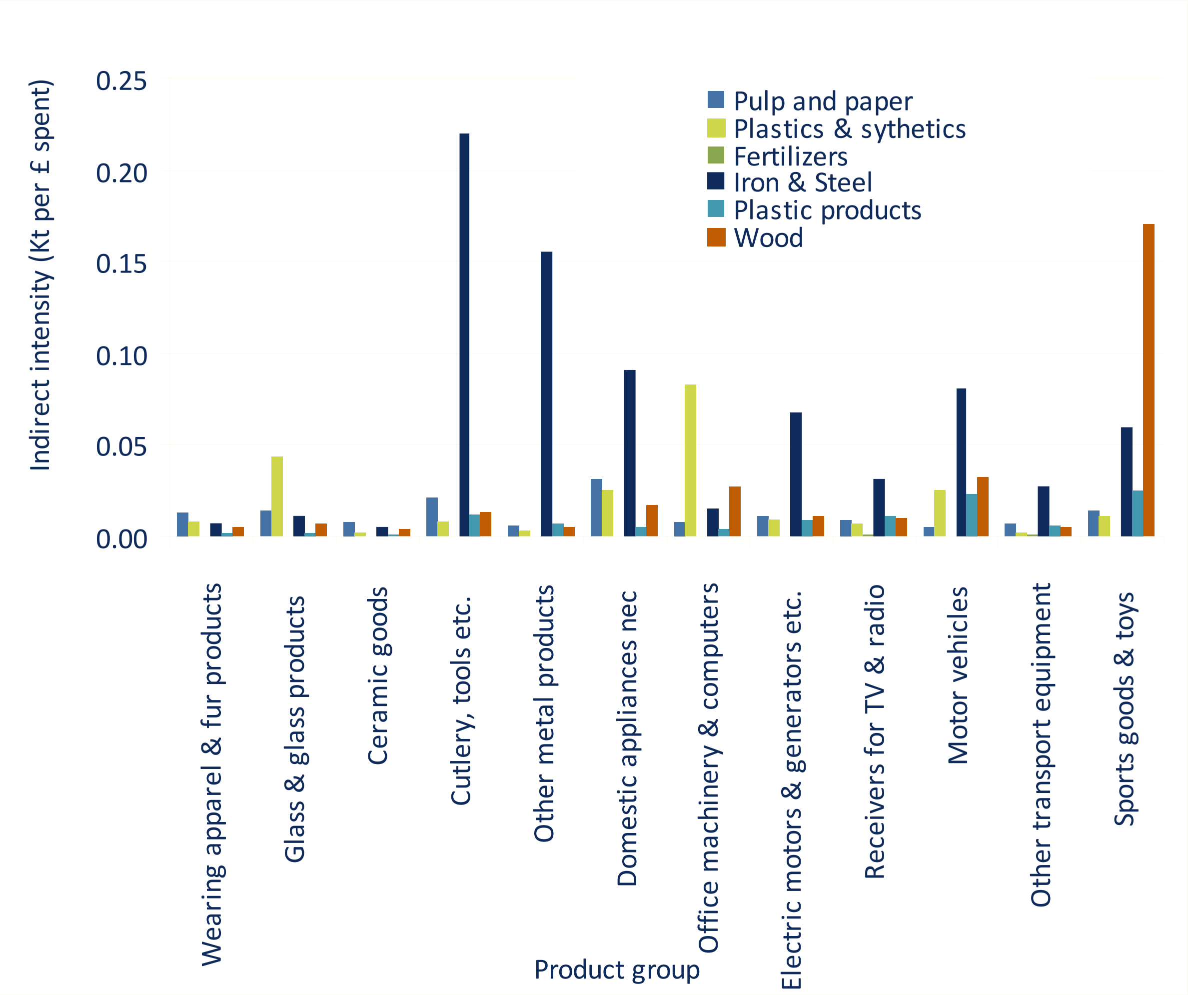
Assumption for the scenario: Extending the lifetime of the product reduces expenditure on the product groups in Table 12. Of the total amount of items that are discarded (e.g. 33% of clothing) the assumption was made that this could be reduced by up to one third.

How the shift in demand for products affects the material impact is dependent on the inter-linkages between products and sectors in the input-output framework. The advantage of using an input-output method is that different product groups can have their indirect impacts (intensities) calculated consistently for a variety of indicators. These intensities are used to calculate total material impacts of strategies by multiplying them with final demand for products. For example, the embedded wood in sports goods and toys is multiplied by the final demand for sports goods and toys to generate an estimate of the total wood impact from consumption of those items.

In the 2009 report the indirect emissions embedded within product supply chains were calculated. For this report the embedded wood, plastic, fertilizers, water etc. within a product was calculated. These 'intensities' (or embedded material impact per pound spent) for different products are shown below in Figure 22 for the product groups affected by the lifetime optimisation strategy.

From an individual product group perspective, the wood embedded in sports goods and toys, for example, is high compared to the embedded pulp and paper or fertilizers. Looking across this range of product groups, embedded iron and steel is the highest of all materials for five product groups including cutlery and tools, other metal products, domestic appliances, electronic motors and motor vehicles. This is a main reason why the lifetime optimisation strategy has a large impact on total iron and steel use.

Figure 22 Indirect material intensity for product groups altered in the lifetime optimisation scenario



Goods to services

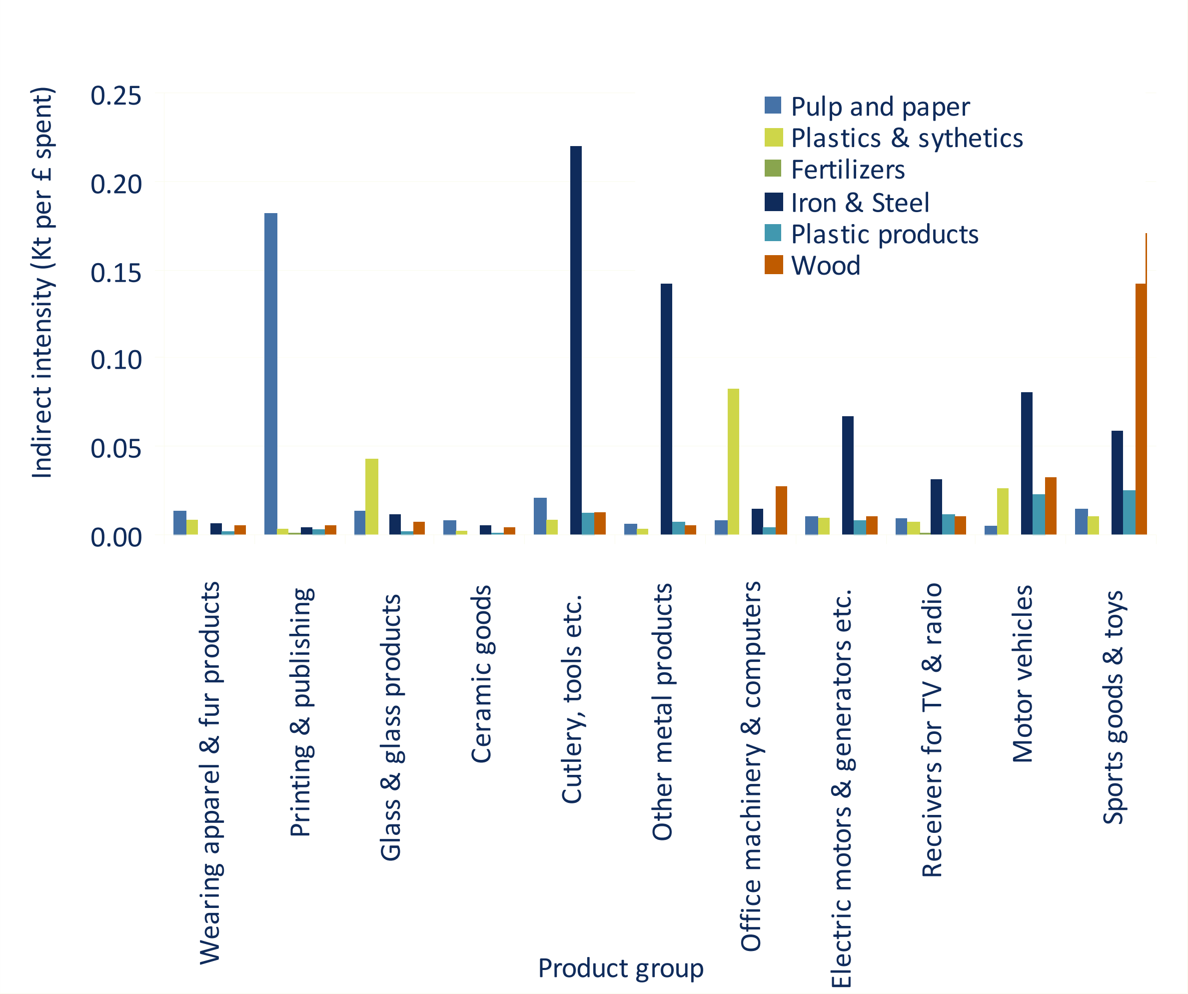
In the 2009 report, key household expenditure categories on material goods that have the possibility to be provided instead through the delivery of services were identified for the goods to services strategy. Of the £732 billion total household spend in 2004, we have identified £148 billion of expenditure 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 strategies have we assumed a complete shift of this expenditure but varying degrees of change.

Assumption: A 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:

- 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 audio equipment, recreational equipment and newspapers and books - A 10% shift in the market by 2020.

The embedded material impact of the product groups which were changed in the goods to services strategy are shown below in Figure 23. In this strategy many of the product groups altered are the same as in the lifetime optimisation strategy, so the impacts across materials will be similar. The noticeable difference is the printing and publishing sector, which has high embedded plastic products; this means that plastic products was higher than for this strategy compared to lifetime optimisation.

Figure 23 Indirect material intensity for product groups altered in the goods to services scenario



6.4 Materials soft-linked to the model

6.4.1 Reference scenario

The results of the reference scenario analysis for the materials that were soft-linked to the model are presented in Table 13. This shows the projected change in material consumption if no resource efficiency strategies were implemented.

Table 13 Reference scenario results for soft-linked materials

Indicator	Material consumption (Kt) 2010	2015	2020	Percentage change 2010-2020
Aluminium	884	959	1,052	19.1%
Cobalt	3.3	3.7	4.0	21.6%
Copper	491	571	611	24.6%
Lithium	2.5	2.7	2.8	12.1%
Rare earths	3.3	3.8	4.1	23.5%
Aggregates	196,533	186,789	184,948	-5.9%
Gypsum and plaster	4,729	4,456	4,372	-7.6%

Most of all of the soft-linked material indicators show an increase in material consumption to 2020 in the reference scenario. This is because they are consumed by sectors that are forecast to increase output over the period of analysis. This includes the metal fabrication sector (a number of materials are used in the production of alloys) and sectors that produce electronic goods. However, aggregates and gypsum and plaster show a reduction as a result of a forecast reduction in the output of the construction sector.

It is interesting to note that lithium consumption does not increase at the same rate as materials such as cobalt, or rare earth metals. These materials are of particular interest because they are used in electronic goods and will increasingly be used in batteries and hybrid electric vehicles. On this basis we could expect consumption of lithium to increase at a similar rate. However, some uses of lithium that will become important in the future are not currently mainstream technologies (such as its use in car batteries) so the current model of the economy does not reflect its future importance in these sectors. The slower rate of increase can also be attributed to a decline in consumption of goods from the glass and pharmaceutical industries. These sectors currently consume nearly half of the lithium used in UK industry.

The percentage of the total material impact associated with the consumption of imported goods is displayed in Table 14. The material impact associated with consumption of imported products is rising steadily over time for all indicators apart from gypsum and plaster. The underlying assumption of a single region model means that differences in material intensity per unit of output in other regions of the world are not considered. This possible trend for increasing impact associated with imports should be explored further, particularly if materials are found to be sourced from areas where local environmental impacts are high.

Table 14 The percentage of total material impact associated with the consumption of imports

Material	Percentage of total material impact from imported products		
	2010	2015	2020
Aluminium	9.8%	10.3%	10.6%
Cobalt	60.1%	61.5%	62.2%
Copper	11.4%	12.8%	13.2%
Lithium	68.7%	70.8%	71.9%
Rare earths	55.5%	57.5%	59.4%
Aggregates	0.4%	0.5%	0.6%
Gypsum and Plaster	0.1%	0.1%	0.1%

6.4.2 The benefits of resource efficiency strategies

In this section, the effect of each strategy on all of the soft-linked material indicators is presented for each material. When analysing the results it is important to note that the strategies have not been designed specifically for the indicator.

Soft-linking the materials to the model rather than incorporating them directly generated two main limitations:

1 The interactions between sectors that buy or sell the material of interest was not available in the same way that it was for the materials added to the model directly. As a result, additional data about the interactions of the sectors for these materials had to be found, with the acknowledgement that this would not capture the full supply-chains in the same way as the model.
2 The lack of interactions between sectors introduces more uncertainty. For example a sector may sell intermediate products to another sector, which might not be affected by the strategy, reducing the impact of the strategy. Alternatively, sectors that indirectly purchase materials may be affected by the strategy, but this would not be fully captured. As the soft-linked materials sit outside the model, it was not possible to analyse these types of inter-industry changes, and consequently, analysis of the production strategies was limited.

Cumulative consumption results

The consumption strategies are modelled for all of the soft-linked materials. In the same way as the other indicators, the effect that each strategy has on the material is dependent on the sector altered by the strategy and its relation to the indicator, the number of sectors altered and the scale of the change.

The results of the consumption strategies for the materials that were soft-linked to the model are presented in Table 15. This shows the projected change in material use if consumption strategies were implemented in parallel. Production strategies are excluded in this table owing to restrictions in the modelling methodology.

Table 15 Quick win scenario results for soft-linked materials

Indicator	Material consumption (Kt)			Change from reference scenario in 2020 (%)
	2010	2015	2020	
Aluminium	884	874	919	-12.6%
Cobalt	3.3	3.2	3.0	-23.4%
Copper	491	495	475	-22.3%
Lithium	2.5	2.4	2.2	-20.0%
Rare earths	3.3	3.4	3.5	-13.5%
Aggregates	196,533	185,904	183,296	-0.9%
Gypsum and Plaster	4,729	4,456	4,372	0.0%

The strategies appear to have minimal impact on the consumption of aggregates and gypsum and plaster. This is due to the fact that they are primarily consumed by sectors which are not affected by the consumption strategies as modelled.

Cumulatively the strategies have a significant impact on the total impact of the other soft-linked materials, all of which show a reduction of about 12% or greater from the reference scenario by 2020. Owing to the materials selected for modelling, the majority of this reduction for most of the materials is caused by strategies that reduce consumption of electrical goods.

The application of one production strategy – lean production

The impact of lean production has also been modelled separately for the soft-linked materials. Modelling the production strategies has a number of limitations for the soft-linked materials (explained below), but lean production has such a large impact on the other indicators, it has been explored as far as limitations will allow. In order to do this, a number of further assumptions had to be made; these are explained in the following paragraphs.

The lean production strategy reduces certain material inputs of a number of industrial sectors; it assumes that they purchase less. For this strategy, it was assumed that a 15% reduction in the material requirement of a number of sectors could be achieved by 2020. The soft-linked materials, such as aluminium do not sit in the input-output table as sectors themselves, so they are not one of the materials considered for reduction in the strategy. So in order to apply this strategy to the materials outside of the model we assume that aluminium (or any other soft-linked material) is one of the inputs that will be reduced. Effectively, we have extended the strategy to incorporate reductions in different materials. This has been done to the same extent as the materials in the original strategy (15%), although this is not necessarily supported by evidence for each material (as explained below in the limitations).

Only a certain number of sectors were assumed to reduce their material input in the original lean production strategy, so we assumed for the soft-linked materials that reductions would only be applied to those sectors that both purchased the material and were in the original strategy. For example, the aluminium requirement of the manufacture of machine tools sector was reduced by 15% from the reference scenario because it is both one of the original sectors that was assumed to have material input reduced in the lean production strategy, and is also one that buys aluminium from the evidence. For this one sector, this would give a reduction of 5.7Kt of aluminium by 2020. Of the total 18 sectors that buy aluminium products, 12 were changed in the original lean production scenario. So in total, lean production reductions across all of these sectors generate a 78Kt reduction from the reference scenario by 2020 for aluminium. This method was applied across all of the soft-linked materials.

The specific limitations of applying the lean production strategy to soft-linked materials are described briefly here:

- The assumption that the same type of reductions can be made for the new materials has been taken, but they may not be able to achieve the same level of resource efficiencies that were determined for the sectors in the 2009 report. For example, we assume that the material requirement of lithium for certain sectors can be reduced, whilst the same level of output is maintained. This may not be true for all materials – lithium may for example, be used optimally within production processes already and cannot be reduced by more than 5%. Consequently, the reductions may be an over or underestimate of what could actually be achieved. In the 2009 report, evidence to inform the efficiency savings was presented and used within the strategies. In order to more fully inform this analysis for new materials more in-depth research would be required for each material and new relevant strategies developed.
- Not having the benefit of the model to define the interactions between sectors means that any changes in a sector that would have indirect links to the material of interest may not be included in the analysis. This could lead to an under or over estimate of the potential change.

Individual strategy results

The following eight graphs (Figures 24-31) show the total material avoided by indicator for each strategy. There are two graphs for aggregates, one without and the other with the lean production strategy result. These are all relative to the reference scenario.

Table 16 summarises the results for all materials and strategies from two perspectives, showing the absolute tonnage reduction and percentage change from the reference scenario by 2020.

In most cases, each strategy gives a reduction from the reference scenario, but for many of the materials, there is still an overall increase in consumption between 2010 and 2020.

Figure 24 Change in aluminium use relative to reference scenario 2010-2010

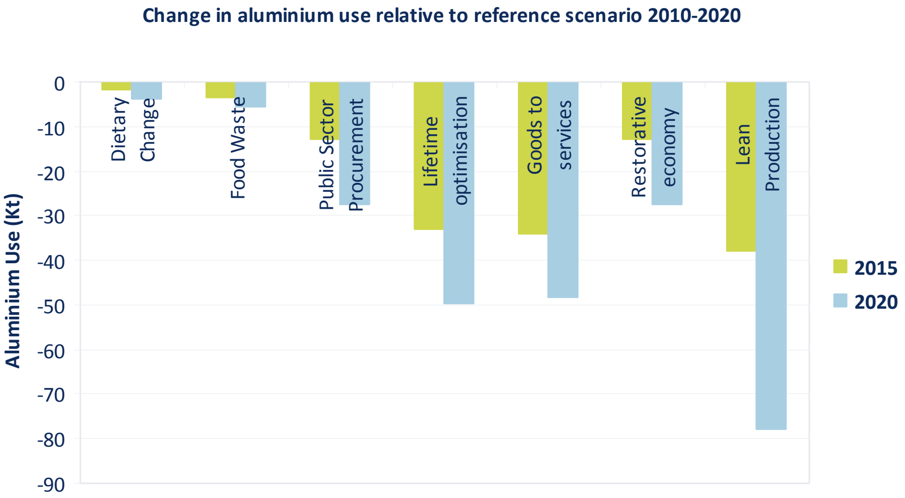


Figure 25 Change in cobalt use relative to reference scenario 2010-2020

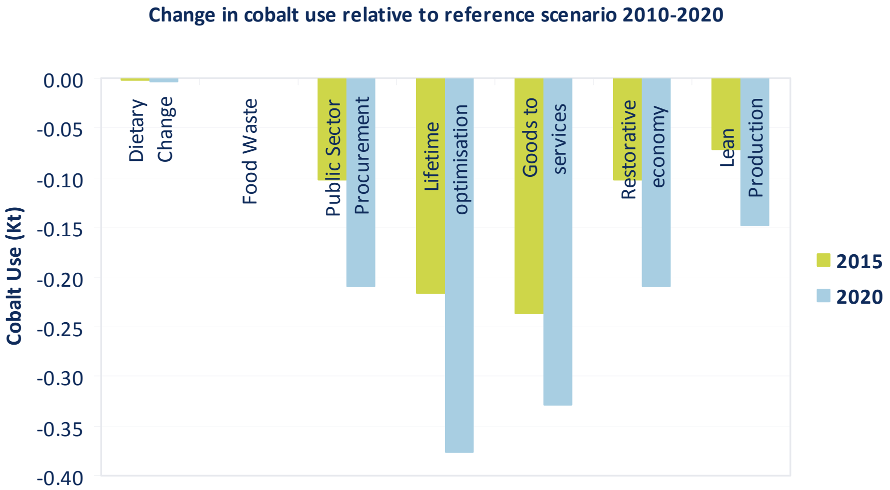


Figure 26 Change in copper use relative to reference scenario 2010-2020

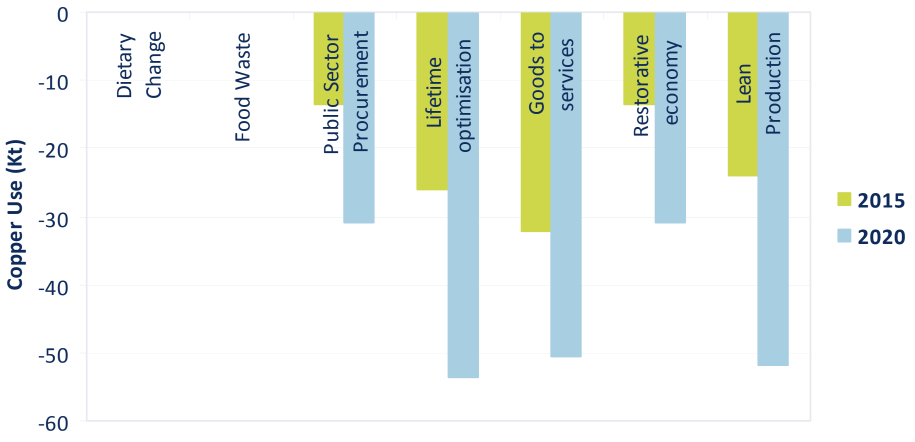


Figure 27 Change in lithium use relative to reference scenario 2010-2020

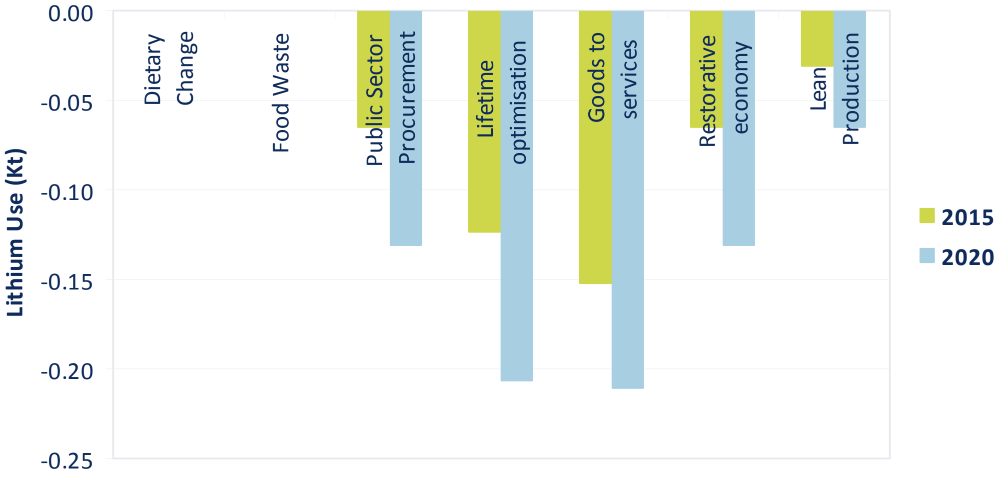


Figure 28 Change in rare earths use relative to reference scenario 2010-2020

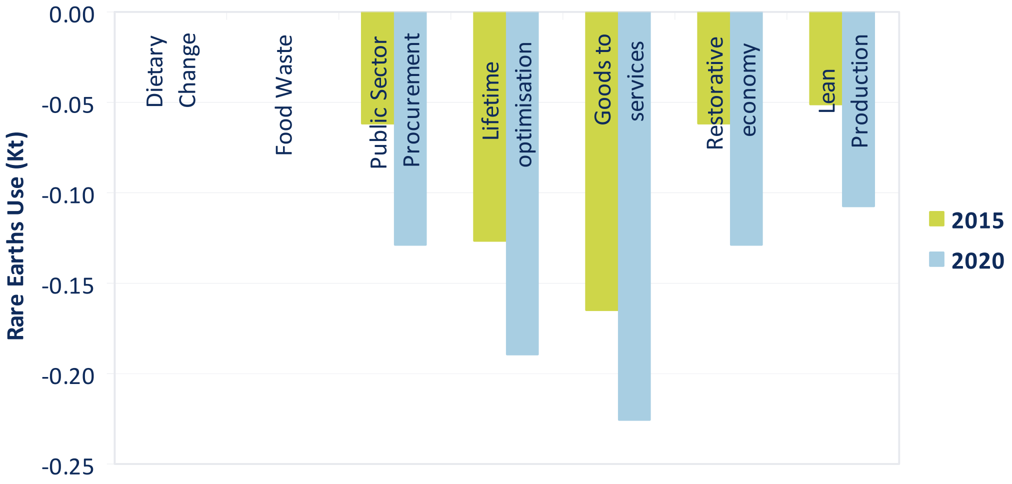


Figure 29 Change in aggregates use relative to reference scenario excl lean production 2010-2020

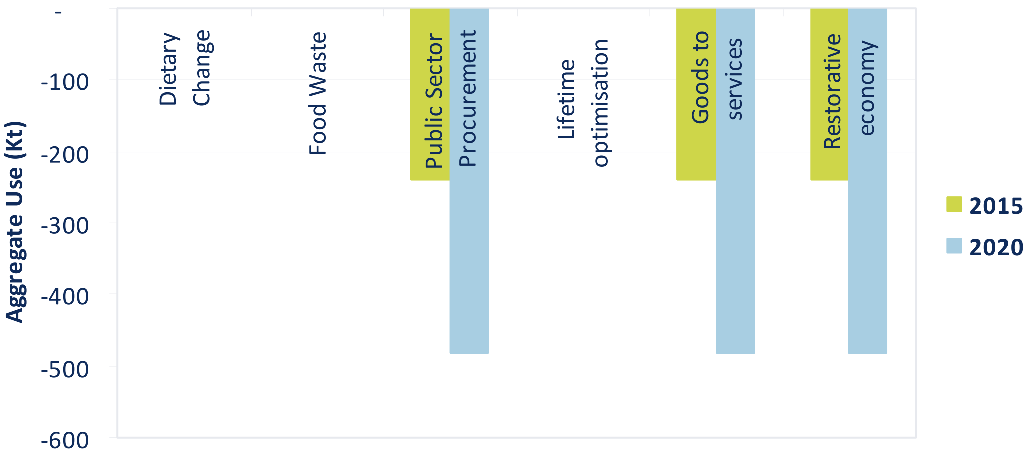


Figure 30 Change in aggregates use relative to reference scenario incl lean production 2010-2020

Figure 31 Change in gypsum and plaster use relative to reference scenario 2010-2020

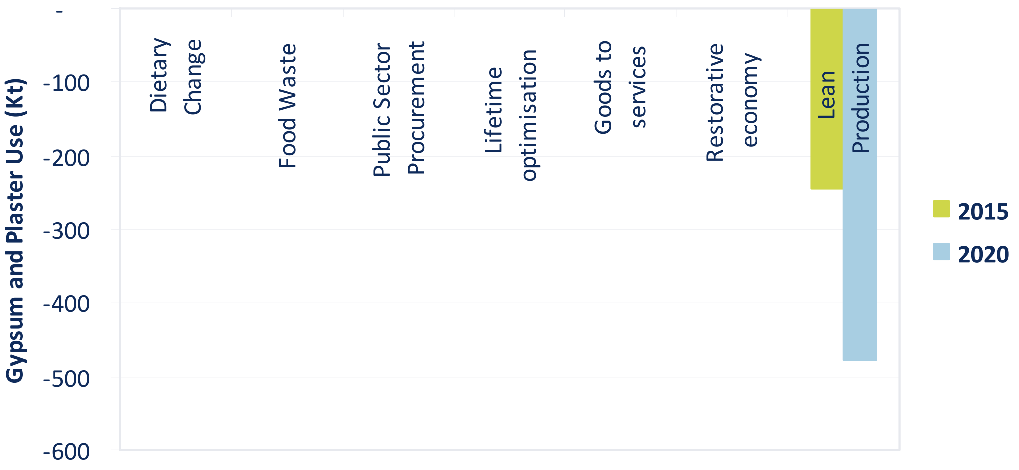


Table 16 The total change in soft-linked material impact from the reference scenario by 2020 and the percentage change between 2010 and 2020 for the strategies.

	Aluminium		**Cobalt**		**Copper**		**Lithium**		**Rare earth metals**		**Aggregates**		**Gypsum and Plaster**	
	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020	Reduction from reference scenario by 2020 (Kt)	Change between 2010-2020
Reference Scenario	~	***19%***	~	***22%***	~	***25%***	~	***12%***	~	***23%***	~	***-6%***	~	***-8%***
Diet	-3.9	***19%***	0	***22%***	0	***25%***	0	***12%***	0.00	***23%***	0	***-6%***	0	***-8%***
Food Waste	-5.5	***18%***	0	***22%***	0	***25%***	0	***12%***	0.00	***23%***	0	***-6%***	0	***-8%***
Government	-27.5	***16%***	-0.21	***15%***	-31	***18%***	-0.13	***7%***	-0.13	***20%***	-480	***-6%***	0	***-8%***
Lifetime optimisation	-49.6	***13%***	-0.38	***10%***	-54	***14%***	-0.21	***4%***	-0.19	***18%***	0	***-6%***	0	***-8%***
Goods to services	-48.1	***14%***	-0.33	***12%***	-51	***14%***	-0.21	***4%***	-0.23	***17%***	-480	***-6%***	0	***-8%***
Restorative economy	-27.5	***16%***	-0.21	***15%***	-31	***18%***	-0.13	***7%***	-0.13	***20%***	-480	***-6%***	0	***-8%***
Cumulative Reduction of demand-side strategies	-133.1	***4%***	-0.92	***-7%***	-137	***-3%***	-0.56	***-10%***	-0.55	***7%***	-1,652	***-7%***	0	***-8%***
Lean Production	-78.0	***10%***	-0.15	***17%***	-52	***14%***	-0.06	***10%***	-0.11	***20%***	-21,572	***-17%***	-476	***-18%***

All materials except gypsum and plaster and aggregates show a trend for increasing consumption in the reference scenario. Three of the five materials show an increasing trend in the reference scenario that is reversed when resource efficiency strategies are applied in combination (cobalt, copper and lithium). This shows that the strategies are having a dramatic effect for these materials. The reduction in material consumption is significantly greater than reductions in GHG emissions from resource efficiency reported in the previous study. This is due to a number of factors:

- The impact comes from a smaller number of sectors (10 to 15 compared to most of the 123 sectors with GHG emissions). This means that the contribution to total impact (the relative intensity) of each sector is higher. If a change is applied to one of these sectors, the overall change in impact will be higher.
- The majority of sectors where the material impact has been allocated are strongly affected by a number of strategies.

In general, strategies that extend the life of goods or reduce the consumption of electronic and electrical goods have the greatest impact. Strategies that reduce food waste have a minimal effect for all materials other than aluminium (which is used in food packaging) because few of the materials selected are used in the food industry.

The consumption strategies that have the greatest impact are lifetime optimisation and goods to services. These strategies have a greater effect because they cause a greater reduction in demand earlier in the quick win strategies. Lean production was the most significant production strategy. For aluminium, copper, aggregates and gypsum, lean production gave the greatest single reduction of all of the strategies. These large reductions were to be expected as lean production affected 34 sectors (compared to 27 for restorative economy, 22 for goods to services, 24 for lifetime optimisation etc.) and also assumed reductions of up to 15% by 2020, where others only assumed 10% in most cases.

6.4.3 Substitution, future technology change and alternative strategies for soft-linked materials

The soft-linked indicators include a number of materials (particularly cobalt, lithium and rare earth metals) that are used for specific purposes (based on their often unique chemical properties) across a range of sectors. For example, rare earth metals are used to produce powerful magnets that are small enough to fit into a range of motors and electronic equipment. This means that the consumption of these materials is strongly affected by a number of strategies because of the range of sectors that use them. The demand-side strategies modelled in this report have a strong, positive effect on reducing the consumption of these resources as a result of the reduction in consumption of the goods that contain the materials.

Based on current technology and production structure, it is uncertain how much more efficiently these materials could be used to produce goods and so the lean production strategy may over estimate the potential savings for these materials from supply-side strategies.

An alternative strategy which could be used to reduce the consumption of these materials is substitution for less restricted materials. However, these materials are used for specific purposes that rely on their particular chemical properties and it is unlikely that they could be substituted without significant technology development.

Primary materials could also be substituted by recycled materials. Due to the very small quantities used in products and the compounds or complexes they are used in these can be difficult to extract. There are some rare metal recycling facilities established such as Umicore in Belgium[1] or the Dowa Holdings facility in Japan[2]. However, wider recycling is currently limited.

As noted previously, the impact of future technology changes have not been considered. This is particularly relevant to the results for rare earths, cobalt and lithium. High strength magnets used in wind turbines and electric vehicles require rare earths and cobalt; rechargeable batteries for electric vehicles require lithium and cobalt; superalloys used in aerospace require rare earth metals and cobalt. These technologies are all forecast to grow dramatically in the near future and it is important to recognise the impact of these on consumption of the selected materials.

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[1] http://www.umicore.com/en/ourBusinesses/recycling/

[2] http://www.dowa.co.jp/en/jigyo/ecosystem_summary.html

7.0 Discussion and recommendations

7.1 Combined indicator scenario analysis

The baseline reduction in water intensity was significant enough to outweigh the increase in demand for products in the reference scenario. For the ecological footprint overall impacts increased despite a projected decline in intensity for a number of land types. The baseline material intensity for the different material indicators was held constant over time due to lack of historical data to project trends, a comparison of technological improvement and demand is therefore not yet possible for materials

There was a dramatic increase in consumption of material indicators of up to 21% (for plastic products). There was less of an increase than expected for some materials, such as lithium which is used for similar purposes as other indicators (cobalt and rare earth metals) but shows half the increase in consumption. This is because the approach used in this study does not account for the forecast growth in consumption from new and emerging technologies.

The majority of indicators followed the same high level trend as GHG emissions, showing a greater reduction from consumption than production strategies. However, some material indicators showed a significant contribution from supply-side strategies, in particular lean production. These strategies were designed to explore changes in GHG emissions, and so further savings could be identified by more targeted strategies, which themselves could yield further GHG emission reductions.

This report found that the most effective strategies were very sensitive to the indicator of interest. Any strategy that changed a product group with a high material intensity per unit of output (either directly through the supply-side strategies or indirectly by reducing final demand for those products) had a significant impact on the total material impact. For example, lifetime optimisation caused reductions for several material indicators, but dietary changes only had a significant effect for those indicators that were associated with the food sector such as fertilizers, water and to some extent the ecological footprint.

7.1.1 Key strategy conclusions

Using the extant GHG emission strategies for the materials, water and ecological footprint demonstrated a number of common conclusions:

1. As expenditure on imports increases so does the associated environmental impact. This is important because it demonstrates that UK consumption and demand for goods has consequences across the globe, in places where the UK government may have limited influence on environmental impacts.
2. Generally, the strategies which gave the greatest emissions reductions also had the greatest benefits for other indicators and no conflicts between indicators were identified.
3. The report confirms the findings of the 2009 report that strategies that address consumption of final products (i.e. demand-side strategies) are just as effective, if not more effective as some production strategies. This reinforces the fact that production strategies cannot be considered on their own; changing the way we use goods as consumers is also crucial.
4. In general, strategies that extend the life of goods or reduce the consumption of electronic and electrical goods have the greatest impact on material consumption. This is because the products that are affected by these strategies use a high proportion of a number of the materials (principally metals) considered in this study.

7.1.2 Strategy applicability

Part of the agreed methodology of this study was that the strategies would remain the same as they did for the 2009 report in order to test their impact across other indicators. This worked well for the demand-side strategies, which changed either inter-industry demand (termed intermediate demand) or the direct intensity of industrial sectors. For some materials (the soft-linked materials) it was more difficult to apply the supply-side strategies, and so with the exception of lean production this was not carried out.

Whilst demonstrating the value of a full supply-chain macro-economic model in understanding how changes to demand in one sector will have knock-on impacts on others, the study also exposes its limitations, allowing only high-level product groups to be analysed rather than single goods.

7.2 Methodological feasibility

A principal element of the project was the addition of new environmental indicators to an established UK input-output emissions model. This was partially achieved, but with a number of limitations and restrictions. In theory, any indicator can easily be added. Unfortunately, environmental indicator data lags behind other economic datasets in terms of consistency, availability and detail. Environmental indicator data seems to remain focused on outputs from processes, with considerable information about discharge into water courses, metal deposit toxicity, or commercial waste for example, but far less data on the resource flows and inputs for the economy as a whole.

Data collection for industry could mirror the existing indicators of a life cycle approach, for example the Wuppertal Institute (2009) advocate collecting bottom-up data on raw materials, water, air and earth movement to generate what they have termed a “Material Input per Unit of Service or Output” using a life cycle approach. If the same data could be sourced at the aggregate industry level, this could be easily embedded within the input-output framework to provide a UK specific, full supply-chain estimate of the material impact per product group, which would be comparable across product groups.

This could complement the life cycle approaches for materials in the same way that the top-down view for emissions accounting gives the complete picture for all of the emissions associated with consumption in the UK. If an indicator set is formulated and agreed, the requirement and means to collect the datasets could be established in a similar way to current emissions or economic datasets.

7.2.1 Modelling limitations

Using structural economic models (models that describe the economy as it is in its present form) for modelling and strategy development has both advantages and disadvantages. The main advantage is that the economy is described as closely as possible to how it is actually behaving at a particular point in time, with all its inefficiencies, social and environmental influences (Duchin, 1998). However, because the model is of the existing economy, any changes to its structure have to be determined explicitly outside of the model, they are not determined implicitly by a set of pre-defined rules.

The relevance for this study is that new technologies or changes to the structure of the economy do not happen dynamically according to rules; they would have to be added and altered in the model independently. For this study, the strategies used have been restricted and no new technologies have been explored. Adding new strategies in the future would allow questions such as the impact of a transition from nickel hydride batteries to lithium in the car industry to be explored.

7.3 Recommendations

This report is a first attempt to incorporate physical data into an input-output approach. It is an initial baseline assessment of data availability for this type of analysis and tests the impacts of strategies developed in the 2009 report on a number of other indicators. The research has faced significant challenges with the availability of data and sets out recommendations below for improving that data.

7.3.1 Availability of material data

Data detailing the use of materials in the UK economy is inconsistent and incomplete.

Recommendation: Support for material specific assessments with high-level or aggregated data collection, to provide an understanding of resource use in the economy as a whole over a year, along with a consistent time series to monitor progress.

If this dataset was sufficiently developed it may be possible to complete a physical input-output table of resource flows between all sectors. An alternative would be to improve existing data and add it to an input-output framework with monetary transactions (as was done for this report). This would enable policy makers to explore whether the material is consumed in a raw form, embedded in an intermediate product or consumed at the point of final demand.

This could then be expanded to investigate imports; providing detail about not only the magnitude of resource imports, but the sectors that they are imported to and the country from which they were sourced. This may be an ambitious dataset, but it would provide considerable insight into possible resource constraints in the future, increased information for consumers about where materials in products are sourced and applications for policy that could help to reduce resource use impacts in key areas.

Recommendation: Improve database of resource and product imports to the UK to help understand impacts of our consumption in a globalised economic system.

This would help highlight any potential local impacts in other countries that were caused by either industrial or consumer demand for resources in the UK. For pollutants such as emissions the intensity per unit of output in different countries means that changing demand for imported products can influence the total emissions associated with consumption in the UK and these emissions have the same impact wherever they are released. Raw materials and resources add an additional layer of complexity because their extraction can have considerable local environmental impacts as well as putting pressure on global resource demand.

7.3.2 Availability of water data

More detailed data is required regarding the consumption and pollution of water from industry and commerce. The data needs to be more disaggregated, more accurate and be measured over time to provide a consistent time series.

Recommendation: regularly and consistently collect data on water use across all sectors of the UK economy.

An improvement to data on water use by industry and commerce overseas would provide more detailed information about the potential embedded water impacts of any products imported to the UK. For this study it had to be assumed that the rest of the world has the same water intensity as the UK due to lack of alternative data.

Recommendation: encourage other countries to record water consumption by different industry; potentially help develop international guidelines for data collection.

7.3.3 Alternative strategies

Some of the assumptions made for the emissions strategies could be altered to answer specific questions about the indicators investigated in this study. Recommendations relating to scenario analysis are set out below.

Recommendation: dataset improvement as recommended in section 7.3.1 above would increase the modelling possibilities for different materials. If deemed appropriate and the data are available, disaggregate the necessary sector into smaller sub-sectors to analyse other materials in an economy-wide model.

New strategies could be created that are more relevant to particular indicators. For example, a number of material indicators are metals that are used in technologies that are predicted to become more prevalent in the future such as the use of lithium in hybrid-electric vehicle batteries. Exploring these types of strategies could require a combination of methodologies (including life cycle assessment) and adjustments within the existing input-output model.

Recommendation: explore indicator specific strategies and model their impacts across a range of environmental indicators.

Recommendation: investigate emerging technologies and their level of dependence on particular materials. This could be delivered by expanding the strategies to look at potential future consumer preferences and demands and then modelling both resources and carbon emissions simultaneously for these new strategies.

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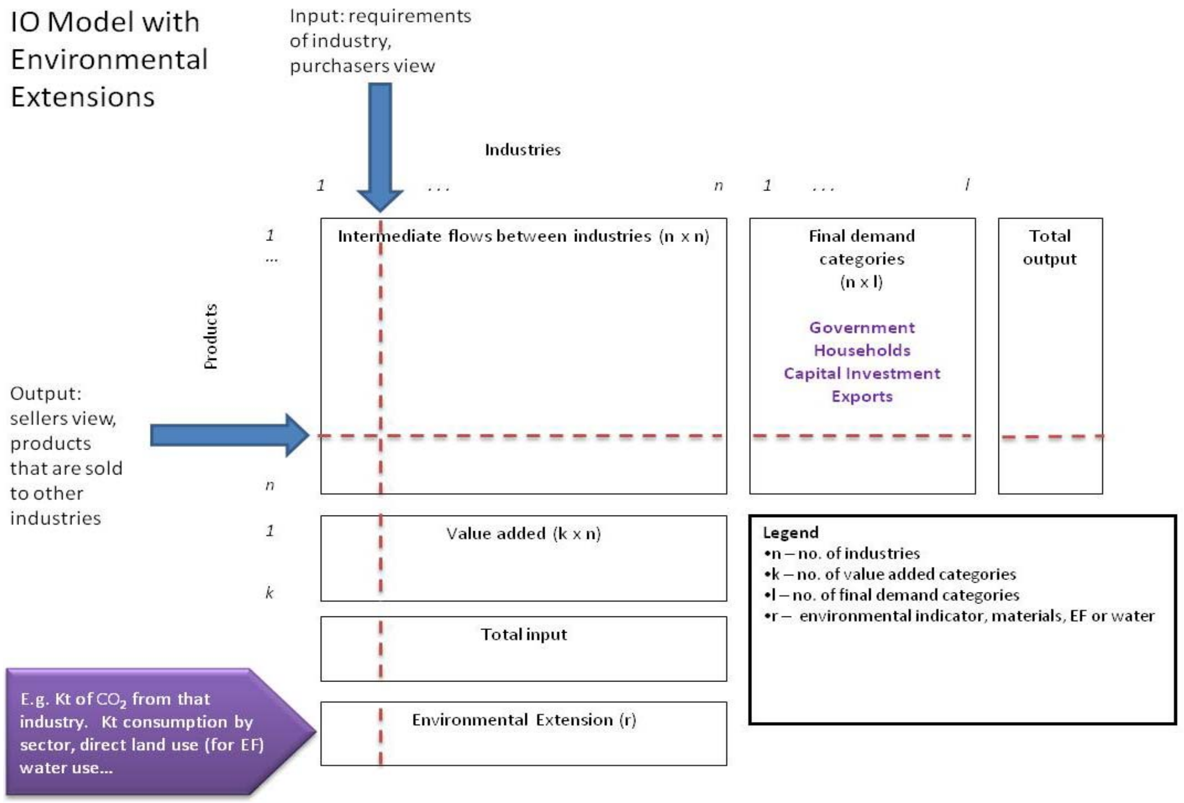
9.0 Appendix A

9.1 Environmentally extended input-output analysis

Data for the indicators that can be added into the input-output model directly are organised by industrial sector (SIC) and added as an environmental extensions shown and in Figure 32. This is a standard framework for input-output modelling, where the flows (usually financial) between industrial sectors of the economy are described and linked to total output of sectors, environmental impacts and final demand. By applying an inversion system developed by Leontief (Leontief, 1986) it is possible to view the impact that is generated along supply chains when demand for a product is altered. This approach is explained in full detail in the 2009 report.

Figure 32 Diagram of an input-output model with environmental extension



9.2 Use of PRODCOM data and its limitations for this study

The PRODCOM data provides a breakdown of all product sales from each sector of UK production, including sales of imported goods (from the EU) in the UK and goods produced in the UK and exported to the EU. Some of these sales are reported in value and mass of product, some are reported only in monetary value, which requires conversion to mass. It was assumed that the mass of material produced by the sector of interest for UK production was the total mass of products sold from UK production (including imports from the EU) excluding products exported for sale outside the UK (not consumed by UK 'production').

This approach is based on the most accurate data currently available in the UK; however it does have a number of limitations:

- PRODCOM reports the mass of products, not materials. Therefore, if a product in the sector of interest contained more than one material this approach would assume that the total mass of the product comprised the material of interest. More detailed analysis of each product would be required to overcome this limitation.

- PRODCOM data is highly disaggregated which makes it extremely difficult to calculate an accurate monetary output for each sector. Therefore the physical output from PRODCOM is compared to a monetary output from the I/O model. The other disadvantage of the high level of disaggregation is that some data are suppressed for confidentiality reasons or due to lack of data.
- PRODCOM does not allow us to distinguish between primary inputs to UK production (for example un-cast iron and steel) and the input of processed or partially processed goods to individual sectors (for example steel girders sold to the construction sector). Both types of sales are aggregated into one total input to UK production. This is particularly problematic for materials such as lithium, cobalt and rare earth metals, where the material may be incorporated in products (such as batteries) that are not listed as products of these materials, but which are incorporated into UK production. The mass of material included in intermediate products is currently excluded from our analysis. More detailed analysis of each material's supply chain or a complete physical input-output table of all the resource flows between sectors and to products would be required to overcome this limitation.
- PRODCOM does not provide detail about resource flows between economic sectors; it only provides the production, imports and exports of products.
- Allocation of soft-linked materials to sectors is based on global statistics of end use by sector. Data relating to the end use of materials in the UK economy would be required to overcome this limitation.
- Soft-linked materials have been allocated to a limited number of sectors based on the evidence available. The strategy impacts have been applied to only those sectors to which the material has been allocated. Any impacts from other sectors indirectly relevant to the material may be omitted. More accurate data relating to the end use of materials in the UK economy would be required to overcome this limitation.

10.0 Appendix B

10.1 Baseline data sources

This section is split into data for indicators that we will put straight through the model as full SIC codes and those where we will apply the scenario outputs from the model to the consumption of the material depending on the sector of end use. The split is as follows:

Indicators that can be allocated to SIC categories directly	**Indicators that will be soft-linked using external consumption data**
Ecological footprint (by 6 land types: cropland, grazing, forest, fishing, carbon and built up land)	Gypsum and plaster products
Water	Aluminium
Iron ore and steel	Copper
Wood and pulp products	Cotton
Plastics (as two categories: “plastic products” and “plastics and synthetic resins”)	Cobalt
Fertilizers (as combined group)	Lithium
	Rare earths
	Aggregates

All of the indicators are dealt with in turn. Those added directly to the model are shown first, followed by a summary of where we extracted the data and the datasets used for verification. Following this all of the indicators that we are soft-linking to the model are then shown in turn. Both the data sources used and contextual information for verification are included.

10.1.1 Indicators added directly to the model

For the indicators that will be allocated to the model directly we have shown a summary total of the data download from the PRODCOM database, EUROSTAT and the ONS. We have also included any relevant external sources used to provide an additional level of verification.

The data that have been run through the model are displayed in Table 17; they are added as the Environmental Indicator to the model (part (r) in Figure 32 above). Explanation of how these figures were derived and the sources of data used are discussed following Table 19.

Note: the environmental impact data provided in this appendix refers to the impact of UK industry, for example the ‘apparent consumption’ of a material indicator by UK industry. This material may originate in the UK or be imported for use by UK industry but is always consumed by UK industry. This data is used to calculate the intensity of UK industry for each indicator (the impact per unit of output).

It was not possible to find equivalent environmental impact data for non-UK industry. Therefore, to calculate the embedded impact in imported goods and services the value of imported goods and services was multiplied by the intensity of relevant UK industrial sectors. This was added to the impact of goods consumed from UK industry to determine the total impact of consumption.

For this reason the ‘apparent consumption’ provided in data below will not equate to total impact figures stated in the main report, since it does not include the indicator embedded in imported goods. This was solely used to calculate impact intensity.

Table 17 Material and ecological footprint direct impacts data

		Total materials for relevant SIC 2007 codes		Ecological footprint data in total gha, 2004					
	Sector name	Total Kt by product group (Kt), 2008	Water use (million m^3)	EF carbon land	EF cropland	EF grazing land	EF built land	EF fishing ground	EF forest land
1	Agriculture, hunting and related service activities	0	15,229	1,483	36,478	10,166	42	0	0
2	Forestry, logging and related service activities	0	0	15	0	0	1	0	4,668
3	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing	0	1,506	102	0	0	2	4,186	0
4	Mining of coal and lignite; extraction of peat	0	5	49	0	0	2	0	0
5	Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction	0	96	5,715	0	0	58	0	0
6	Mining of metal ores	0	0	6	0	0	0	0	0
7	Other mining and quarrying	0	13	265	0	0	10	0	0
8	Production, processing and preserving of meat and meat products	0	382	454	0	0	5	0	0
9	Processing and preserving of fish and fish products; fruit and vegetables	0	32	257	0	0	3	0	0
10	Vegetable and animal oils and fats	0	8	59	0	0	1	0	0
11	Dairy products	0	28	237	0	0	2	0	0
12	Grain mill products, starches and starch products	0	15	128	0	0	1	0	0
13	Prepared animal feeds	0	17	132	0	0	1	0	0
14	Bread, rusks and biscuits; manufacture of pastry goods and cakes	0	39	295	0	0	3	0	0
15	Sugar	0	6	47	0	0	0	0	0
16	Cocoa; chocolate and sugar confectionery	0	17	128	0	0	1	0	0
17	Other food products	0	23	202	0	0	2	0	0
18	Alcoholic beverages	0	33	252	0	0	3	0	0
19	Production of mineral waters and soft drinks	0	16	122	0	0	1	0	0
20	Tobacco products	0	5	12	0	0	23	0	0

21	Preparation and spinning of textile fibres	0	2	47	0	0	2	0	0
22	Textile weaving	0	2	83	0	0	4	0	0
23	Finishing of textiles	0	4	44	0	0	2	0	0
24	Made-up textile articles, except apparel	0	10	118	0	0	5	0	0
25	Carpets and rugs	0	5	75	0	0	3	0	0
26	Other textiles	0	3	86	0	0	4	0	0
27	Knitted and crocheted fabrics and articles	0	2	75	0	0	3	0	0
28	Wearing apparel; dressing and dying of fur	0	12	44	0	0	13	0	0
29	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery and harness	0	1	9	0	0	2	0	0
30	Footwear	0	1	8	0	0	2	0	0
31	Wood and wood products, except furniture	24,138	26	579	0	0	23	0	0
32	Pulp, paper and paperboard	11,760	8	332	0	0	24	0	0
33	Articles of paper and paperboard	0	32	817	0	0	5	0	0
34	Publishing, printing and reproduction of recorded media	0	93	394	0	0	17	0	0
35	Coke, refined petroleum products and nuclear fuel	0	184	4,640	0	0	23	0	0
36	Industrial gases, dyes and pigments	0	36	392	0	0	23	0	0
37	Other inorganic basic chemicals	0	32	321	0	0	26	0	0
38	Other organic basic chemicals	0	48	939	0	0	24	0	0
39	Fertilisers and nitrogen compounds	4,639	26	408	0	0	23	0	0
40	Plastics and synthetic rubber in primary forms	4,536	1	453	0	0	23	0	0
41	Pesticides and other agro-chemical products	0	8	76	0	0	24	0	0
42	Paints, varnishes and similar coatings, printing ink and mastics	0	64	50	0	0	24	0	0
43	Pharmaceuticals, medicinal chemicals and botanical products	0	88	442	0	0	22	0	0
44	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	0	81	135	0	0	23	0	0
45	Other chemical products	0	25	91	0	0	25	0	0
46	Man-made fibres	0	4	147	0	0	26	0	0
47	Rubber products	0	1	226	0	0	23	0	0
48	Plastic products	5,812	5	731	0	0	22	0	0
49	Glass and glass products	0	10	385	0	0	23	0	0

50	Ceramic goods	0	4	107	0	0	21	0	0
51	Bricks, tiles and construction products, baked in clay	0	3	194	0	0	21	0	0
52	Cement, lime and plaster	0	4	2,865	0	0	2	0	0
53	Articles of concrete, plaster and cement; cutting, shaping and finishing of stone; manufacture of other non-metallic products	0	24	205	0	0	7	0	0
54	Basic iron and steel and of ferro-alloys; manufacture of tubes and other first processing of iron and steel	13,581	40	5,183	0	0	23	0	0
55	Basic precious and non-ferrous metals	0	22	1,017	0	0	24	0	0
56	Casting of metals	0	13	69	0	0	24	0	0
57	Structural metal products	0	72	160	0	0	7	0	0
58	Tanks, reservoirs and containers of metal; manufacture of central heating radiators and boilers; manufacture of steam generators	0	17	39	0	0	2	0	0
59	Forging, pressing, stamping and roll forming of metal; powder metallurgy; treatment and coating of metals	0	80	173	0	0	8	0	0
60	Cutlery, tools and general hardware	0	9	46	0	0	2	0	0
61	Other fabricated metal products	0	35	103	0	0	4	0	0
62	Machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines	0	6	89	0	0	5	0	0
63	Other general purpose machinery	0	16	133	0	0	7	0	0
64	Agricultural and forestry machinery	0	2	19	0	0	1	0	0
65	Machine tools	0	2	20	0	0	1	0	0
66	Other special purpose machinery	0	6	80	0	0	4	0	0
67	Weapons and ammunition	0	6	30	0	0	2	0	0
68	Domestic appliances not elsewhere classified	0	6	37	0	0	2	0	0
69	Office machinery and computers	0	7	32	0	0	26	0	0
70	Electric motors, generators and transformers; manufacture of electricity distribution and control apparatus	0	4	93	0	0	11	0	0
71	Insulated wire and cable	0	1	16	0	0	2	0	0
72	Electrical equipment not elsewhere classified	0	5	85	0	0	10	0	0
73	Electronic valves and tubes and other electronic components	0	2	29	0	0	8	0	0
74	Television and radio transmitters and line for telephony and line telegraphy	0	1	36	0	0	9	0	0

75	Television and radio receivers, sound or video recording or reproducing apparatus and associated goods	0	2	25	0	0	6	0	0
76	Medical, precision and optical instruments, watches and clocks	0	9	99	0	0	22	0	0
77	Motor vehicles, trailers and semi-trailers	0	55	467	0	0	23	0	0
78	Building and repairing of ships and boats	0	6	43	0	0	3	0	0
79	Other transport equipment	0	7	41	0	0	3	0	0
80	Aircraft and spacecraft	0	3	209	0	0	16	0	0
81	Furniture	0	46	404	0	0	14	0	0
82	Jewellery and related articles; manufacture of musical instruments	0	2	28	0	0	1	0	0
83	Sports goods, games and toys	0	4	43	0	0	2	0	0
84	Miscellaneous manufacturing not elsewhere classified; recycling	0	23	228	0	0	6	0	0
85	Production and distribution of electricity	0	2,565	44,407	0	0	23	0	0
86	Gas; distribution of gaseous fuels through mains; steam and hot water supply	0	1,373	537	0	0	23	0	0
87	Collection, purification and distribution of water	0	381	264	0	0	23	0	0
88	Construction	0	19	2,356	0	0	23	0	0
89	Sale, maintenance and repair of motor vehicles, and motor cycles; retail sale of automotive fuel	0	32	645	0	0	23	0	0
90	Wholesale trade and commission trade, except of motor vehicles and motor cycles	0	70	1,353	0	0	22	0	0
91	Retail trade, except of motor vehicles and motor cycles; repair of personal and household goods	0	70	1,300	0	0	527	0	0
92	Hotels and restaurants	0	56	681	0	0	335	0	0
93	Transport via railways	0	3	526	0	0	627	0	0
94	Other land transport; transport via pipelines	0	17	5,884	0	0	932	0	0
95	Water transport	0	1	6,709	0	0	26	0	0
96	Air Transport	0	5	9,635	0	0	23	0	0
97	Supporting and auxiliary transport activities; activities of travel agencies	0	21	244	0	0	23	0	0
98	Post and courier activities	0	6	121	0	0	5	0	0
99	Telecommunications	0	16	328	0	0	14	0	0

100	Financial intermediation, except insurance and pension funding	0	36	94	0	0	37	0	0
101	Insurance and pension funding, except compulsory social security	0	21	87	0	0	5	0	0
102	Activities auxiliary to financial intermediation	0	4	89	0	0	16	0	0
103	Real estate activities with own property; letting of own property, except dwellings	0	19	64	0	0	36	0	0
104	Letting of dwellings, including imputed rent	0	49	179	0	0	101	0	0
105	Real estate activities on a fee or contract basis	0	3	12	0	0	7	0	0
106	Renting of machinery and equipment without operator and of personal and household goods	0	11	269	0	0	22	0	0
107	Computer and related activities	0	21	84	0	0	26	0	0
108	Research and development	0	2	75	0	0	24	0	0
109	Legal activities	0	10	73	0	0	137	0	0
110	Accounting, book-keeping and auditing activities; tax consultancy	0	4	34	0	0	64	0	0
111	Market research and public opinion polling; business and management consultancy activities; management activities	0	14	97	0	0	181	0	0
112	Architectural and engineering activities and related technical consultancy; technical testing and analysis	0	13	102	0	0	192	0	0
113	Advertising	0	9	71	0	0	133	0	0
114	Other business services	0	27	257	0	0	481	0	0
115	Public administration and defence; compulsory social security	0	61	2,112	0	0	168	0	0
116	Education	0	47	838	0	0	661	0	0
117	Human health and veterinary activities	0	53	913	0	0	147	0	0
118	Social work activities	0	24	401	0	0	64	0	0
119	Sewage and refuse disposal, sanitation and similar activities	0	7	588	0	0	75	0	0
120	Activities of membership organisations not elsewhere classified	0	4	102	0	0	17	0	0
121	Recreational, cultural and sporting activities	0	22	361	0	0	109	0	0
122	Other service activities	0	6	191	0	0	22	0	0
123	Private households with employed persons	0	0	52	0	0	0	0	0

Fertilizers

Data on fertilizers was added to the model directly, meaning that a detailed consumption breakdown was not required as the model provides the supply chain interactions.

Data to be added to the model as an environmental extension is shown in Table 18 below.

Table 18 EUROSTAT PRODCOM database, 2008

	Production	**Export Quantity**	**Import Quantity**	**TOTAL: Prod-Export+Imps**
Kt	2,879	140	1,900	**4,639**

Additional verification data from Nitrogen UK report (undated): UK sector (natural & industrial) and nitrogen content (kilotonnes). This suggests a total usage figure of 4,575Kt per annum. The total 4,639 Kt from EUROSTAT and 4,575 Kt from the Nitrogen UK report are similar. **The EUROSTAT estimate of 4,639 Kt was used for this study** for consistency with the other indicators and it is verified by the Nitrogen UK report.

Iron ore and steel

This was added to the model directly, so detailed consumption breakdown is not required (the model provides the supply chain interactions). Additional detail was obtained from Dahlström et al (2004)

Table 19 Iron, Steel and Aluminium in the UK, Dahlström et al 2004

Iron ore and steel MFA		**Ktonnes kt**
Iron ore	Imports	15,112
Pig iron	Imports	160
	Exports	7
Crude steel	Imports	393
	Exports	751
Iron & Steel industry products	Imports	7,697
	Exports	6,089
Iron & Steel in new goods	Imports	7,305
	Exports	5,592
Prompt and end of life scrap	Imports	171
	Exports	4,818
	Total apparent consumption	**13,581**

UK Steel (2006) suggests steel supply to the UK market of 13,800Kt. These statistics are similar for 2004 and 2006 from the two different sources. However, these two data sources **do not match up** with the ONS and EUROSTAT data which are as follows:

Table 20 PRODCOM ONS data, 2008. Divisions: 2420, 2431, 2432, 2433, 2434

	PRODCOM sales	Intra EU exports	Intra EU imports	Extra EU exports	Extra EU imports	TOTAL:
Kt	1,071	769	857	434	667	1,392

Table 21 PRODCOM EUROSTAT data, 2008. Divisions: 2410, 2420, 2431, 2432, 2433, 2434

	Production	Export quantity	Import quantity	TOTAL: Prod-Export+Imps
Kt	1,082	5,396	4,111	-203

Due to the similarity of the following two sources UK Steel Annual Review and Dahlström et al. (2004), the decision was taken to use an external source rather than PRODCOM ONS or EUROSTAT output. **We selected the slightly lower estimate of 13,581 Kt from Dahlström et al. to take a conservative approach.**

Plastics

Plastics are separated into two different categories in the SIC codes – “Plastic products” and “Plastics and synthetic rubber in primary forms”. The tables below show the data that were entered into the model in Kt. These two plastic categories were run through the model separately for analysis. They were both added to the model directly, so detailed consumption breakdown is not required (the model provides the supply chain interactions).

Table 22 PRODCOM EUROSTAT data, 2008. Division 22, 27, 32 and 33: 2221, 2222, 2223, 2229, 2733, 3299, 3319, 3320

Plastic products

	Production	Export Quantity	Import Quantity	TOTAL: Prod-Export+Imps
Kt	4,330	1,099	2,581	5,812

For consistency with other indicators the EUROSTAT figure of **5,812 Kt was input into the model.**

Table 23 PRODCOM EUROSTAT data, 2008. Division 20: 2016 and 2017

Plastic and synthetic rubber in primary forms

	Production	Export Quantity	Import Quantity	Prod-Export+Imps
Kt	2,854	1,721	3,403	4,536

For consistency with other indicators the EUROSTAT figure of **4,536 Kt was input into the model.**

Wood and pulp products

This was added to the model directly, so detailed consumption breakdown is not required (the model provides the supply chain interactions).

In the SIC codes “Wood and wood products” and “Pulp, paper and paperboard” are separated into two categories, they were therefore run through the model separately for analysis. The tables below show the data that was entered into the model (Prod-Export+Imps) in Kt.

Wood and wood products

Table 24 PRODCOM ONS data, 2008. Division 16: 1610, 1621, 1622, 1623, 1624 and 1629

	Prodcom Sales	Intra EU Exports	Intra EU Imports	Extra EU Exports	Extra EU Imports	Total (Kt)
Kt	8,869	12,101	21,784	1,006	6,592	24,138

Table 25 PRODCOM EUROSTAT data, 2008. Division 16

	Production	Export Quantity	Import Quantity	Total (Kt)
Kt	9,057	2,582	17374	23,850

Table 26 Forestry Commission dataset

Additional supplementary/cross checking data from the Forestry Commission[3]:

2008	UK Production	Imports	Exports	Apparent consumption
kt	9,391	16232	1264	17,989

In this instance the PRODCOM ONS value of 24,138 Kt was taken due to the more detailed code level data available. It is higher than the Forestry Commission data most probably due to the broader definition of wood and wood products, rather than just the raw material wood. The PRODCOM ONS data matches more closely the SIC definition for the model.

Pulp, paper and paperboard

Table 27 PRODCOM ONS data, 2008. Division 21

Prodcom Sales	Intra EU Exports	Intra EU Imports	Extra EU Exports	Extra EU Imports	Total (Kt)
9,737	1,155	6,749	330	2,502	17,503

Table 28 PRODCOM EUROSTAT data, 2008. Division 21.2

	Production	Export Quantity	Import Quantity	Total (Kt)
Kt	4,663	1,578	8,675	11,760

Table 29 Forestry Commission dataset

Additional supplementary/cross checking data from the Forestry Commission:

2008	UK Production	Imports	Exports	Apparent consumption
Kt	4,983	7,423	1,030	11,376

PRODCOM ONS and EUROSTAT downloads are consistent and similar to the Forestry Commission estimates. The Forestry Commission has regular statistical updates of wood production and imports/exports which are compiled from UK overseas trade statistics and industry surveys.

‘Wood and wood products, except furniture’ and ‘Pulp, paper and paperboard’ are two SIC sectors in the current model so the supply chain impacts will be captured within the model. **The EUROSTAT figure for pulp, paper and paperboard of 11,760Kt was chosen due to its similarity with the Forestry Commission data.**

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[3] http://faostat.fao.org/portals/_faostat/documents/forestproductsdefinitions.htm

Water

The data in the table below was backcast to 2004 and disaggregated to 123 industrial sectors using industrial output levels by sector (from the ONS). A time series of agricultural data from the UN's Food and Agriculture Organisation was available which allowed the projection of a baseline for the reference scenario for the agricultural sector only.

Table 30 ONS data 2006/2007, extracted from Environmental Accounts, public water supply, plus direct abstraction. Agricultural data: UNs Food and Agriculture Organisation.

	Water use by year for UK sectors, Million cubic meters							
Sector	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Agriculture	16,418	15,206	14,595	15,536	15,168	15,229	14,703	14,306
Livestock	-	-	-	-	-	-	-	372
Fisheries	-	-	-	-	-	-	-	1,284
Mining and extraction	-	-	-	-	-	-	-	107
Food, drink and tobacco	-	-	-	-	-	-	-	215
Textiles	-	-	-	-	-	-	-	20
Pulp, paper, printing and publishing	-	-	-	-	-	-	-	138
Fuel processing	-	-	-	-	-	-	-	170
Chemicals	-	-	-	-	-	-	-	308
Rubber and plastics	-	-	-	-	-	-	-	6
Mineral products	-	-	-	-	-	-	-	31
Metal manufacturing and products	-	-	-	-	-	-	-	274
Manufacture of machinery	-	-	-	-	-	-	-	16
Electrical equipment	-	-	-	-	-	-	-	33
Transport equipment	-	-	-	-	-	-	-	86
Other manufacturing including recycling	-	-	-	-	-	-	-	37
Electricity and gas production	-	-	-	-	-	-	-	3,802
Construction	-	-	-	-	-	-	-	18
Wholesale, hotels and catering	-	-	-	-	-	-	-	264
Education and health	-	-	-	-	-	-	-	182
Other services	-	-	-	-	-	-	-	372
Domestic	-	-	-	-	-	-	-	3,270

10.1.2 Material data that are soft-linked to the model

The data we have collected for the soft-linked materials is then shown in following section of this report. This section includes tables that show how the consumption was allocated across sectors.

Note: the consumption data provided in this section refers to the apparent consumption by UK industry to produce goods and services consumed in the UK. This material may originate in the UK or be imported for use by UK industry but is always consumed by UK industry. This data is used to calculate the intensity of UK industry for each indicator (the impact per unit of output).

It was not possible to find equivalent environmental impact data for non-UK industry, except for aluminium, where actual data is used. To calculate the quantity of material embedded in imported goods and services the value of imported goods and services was multiplied by the intensity of relevant UK industrial sectors. This was added to the impact of goods consumed from UK industry to determine the total impact of consumption. It was assumed that the proportion of use of the soft-linked materials was the same in the rest of the world as in the UK.

For this reason the 'apparent consumption' provided in data below will not equate to total impact figures stated in the main report, since it does not include the material embedded in imported goods. This data was solely used to calculate impact intensity.

Aluminium

Detail on aluminium flows has been obtained from Dahlström et al (2004).

Table 31 Extracted from Dahlström et al. 2004, figure 3.8

Product		**000 tonnes (Kt)**
Alumina	Imports	703,979
Ingots, billets and slabs (unwrought)	Imports	346,892
	Exports	263,342
Semis and casting	Imports	404,800
	Exports	218,900
Aluminium in new goods	Imports	968,005
	Exports	882,896
Prompt and end of life scrap	Imports	110,076
	Exports	208,289
	Total apparent consumption	**875,216**
	Total in imported goods	**85,109**

The robustness of the data source and level of detail provided meant that **the Dahlström et a (2004) figure of 875,216 Kt was used in calculations.**

Aluminium was allocated to sectors based on the following end uses:

Table 32 Aluminium End Use Source: London Metal Exchange

End Use	%	Relevant Sector in the Model	
Packaging	21	11	Dairy products
		14	Bread and biscuits
		17	Other food products
		18	Alcoholic beverages
		19	Soft drinks
		92	Hotels and catering
Household equipment	2	60	Cutlery tools etc
Machinery	15	62	Mechanical power equipment
		63	General purpose machinery
		64	Agricultural machinery
		65	Machine tools
		66	Special purpose machinery
Electrical equipment	7	68	Domestic appliances
		69	Office machinery
		72	Electrical equipment
		75	Television and radio receivers
Vehicles	25	77	Transport
Construction	30	88	Building/construction

Table 33 PRODCOM ONS data, 2008.

Cobalt

Trade Unit	Prodcom Sales	Intra EU Exports	Intra EU Imports	Extra EU Exports	Extra EU Imports	Apparent consumption
Kt	0	0.48	0.18	0.21	0.01	-0.51

Because of suppressed data PRODCOM returned a negative number for cobalt consumption so an alternative source was investigated.

Data from EC (2010) and the Cobalt Development Institute that state that the EU consumed 26.5Kt of Cobalt in 2007. There was no estimate of the proportion consumed by each member state, therefore, the average proportion of EU copper consumption (which supplies similar UK industries) allocated to the UK in WBMS data was used to estimate the proportion of UK consumption of EU Cobalt. This was calculated to be 5.1%.

Therefore, estimated **UK consumption of cobalt was 1.35 kt was used in calculations.**

Table 34 Cobalt End Use, Source: Cobalt Development Institute (2009)

Cobalt was allocated to sectors based on the following end uses:

End Use	%	Relevant Sector in the Model	
Superalloy	19	80	Aircraft and spacecraft
		62	Machinery for prod and use of mechanical power
Hardfacing and other alloy	4	77	Motor vehicles
Magnets - all types	7	77	Motor vehicles
		62	Machinery for prod and use of mechanical power
		72	Electrical equipment not elsewhere classified
Hard materials - carbides, diamond tooling	14	65	Machine tools
Colours - glass, enamels, plastics, ceramics, artists colours, fabrics	10	49	Glass and glass prods
		50	Ceramic goods
		42	Paints and varnish
		21	Preparation and spinning of textile fibres
Catalysts	9	40	Plastics and synthetic rubbers
Feedstuffs, anodising, recording media electrolysis	4	13	Prepared animal feeds
		59	Forging, pressing, stamping and roll forming of metal; powder metallurgy; treatment and coating of metals
		75	Television and radio receivers, sound or video recording or reproducing apparatus and associated goods
Batteries	27	72	Electrical equipment not elsewhere classified
		69	Office machinery and computers
		77	Motor vehicles
Tyre adhesives, soaps, driers (paint/ink)	6	40	Plastics and synthetic rubbers
		44	Soaps and detergents
		42	Paints and varnish

Table 35 PRODCOM ONS data, 2008. Division 24: 2444

Copper

	Prodcom Sales	Intra EU Exports	Intra EU Imports	Extra EU Exports	Extra EU Imports	Total
Kt	115	71	320	34	49	380

Table 36 PRODCOM EUROSTAT data, 2008.

	Production	Export Quantity	Import Quantity	Prod-Export+Imps
Kt	149	113	378	415

The two sources provided results at a similar order of magnitude. For consistency with other indicators **the EUROSTAT figure of 380 Kt was used in calculations.**

Copper was allocated to sectors based on the following end uses:

Table 37 Copper End Use Source: International Copper Association

End Use	**%**	**Relevant Sector in the Model**	
Construction - Plumbing	6	88	Construction
Construction - Building plant	1		
Construction - Architecture	2		
Construction - Communications	1		
Construction - Electrical Power	16		
Infrastructure - Power Utility	11	85	Electricity production and dist
Intrastructure - telecoms	4	99	Telecommunications
Equip. Manuf. - Industrial	19	63	General purpose machinery
		64	Machine tools
		65	Special purpose machinery
Equip. Manuf. - Automotive	8	77	Motor vehicles
Equip. Manuf. - Other Transport	5	79	Other transport equipment
Equip. Manuf. - Consumer and gen prods	8	72	Electrical equipment nec
Equip. Manuf. - Cooling	7	75	TV and radio receivers etc
Equip. Manuf. -Electronic	4	68	Domestic appliances
Equip. Manuf. - Diverse	9	69	Office machinery and computers

Table 38 PRODCOM ONS data, 2008.

Lithium

Unit	Prodcom Sales	Intra EU Exports	Intra EU Imports	Extra EU Exports	Extra EU Imports	Apparent consumption
Kt	0	0.19	0.50	0.07	0.77	1.01

This was the only source of data but was consistent with other indicators so **the EUROSTAT figure of 1.01 Kt was used in calculations**. This consumption was allocated to sectors based on the following end uses:

Table 39 Lithium End Use Source: U.S. Geological Survey (2010)

End Use	**%**	**Relevant Sector in Model**	
Ceramics and glass	31	50	Ceramic goods
		49	Glass and glass products
Batteries	23	72	Electrical equipment not elsewhere classified
		69	Office machinery and computers
		77	Motor vehicles
Lubricating greases	10	35	Refined petroleum products
Air treatment	5	72	Electrical equipment not elsewhere classified
Continuous casting	4	56	Casting of metals
Primary aluminium production	3	55	Basic precious and non-ferrous metals
Other uses	24	43	Pharmaceuticals

Table 40 PRODCOM ONS data, 2008.

Rare Earths

	Prodcom Sales	Intra EU Exports	Intra EU Imports	Extra EU Exports	Extra EU Imports	Apparent consumption
Kt	0	0.56	0.78	0.72	2.14	1.6

This was the only source of data but was consistent with other indicators so **the EUROSTAT figure of 1.6 Kt was used in calculations**. This consumption was allocated to sectors based on the following end uses:

Table 41 Rare Earth End Use Source: Oakdene Hollins (2010)

End use	**%**	**Relevant sector in model**	
Magnets	21	77	Motor vehicles
		72	Electrical equipment not elsewhere classified
		85	Production and distribution of energy
Catalysts	19	77	Motor vehicles
		35	Refined petroleum products
Metal Alloys	18	55	Basic precious and non-ferrous metals
		59	Forging, pressing, stamping and roll forming of metal; powder metallurgy; treatment and coating of metals
		61	Other fabricated metal products
Polishing	12	44	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
Glass	10	49	Glass and glass products
Phosphors	7	78	TV and radio receivers etc
		69	Office machinery and computers
		72	Electrical equipment not elsewhere classified
Ceramics	6	50	Ceramic goods
Other	7	76	Medical, precision and optical instruments
		43	Pharmaceuticals

Aggregates

The DCLG (2005) Aggregate Minerals surveys from the ONS are the only comprehensive measurement of apparent consumption of primary aggregates by region (and now sub-region). Total apparent consumption of primary aggregates was 173.4 Mt in 2005, of which 160 Mt was used in England and 13.5 Mt in Wales. Total consumption is somewhat higher than total sales (172.7 Mt) because it includes imports from outside England and Wales, mainly from Scotland. However, total unallocated sales of unknown destination were just over 3 Mt in 2005, somewhat greater than in 2001 (1 Mt). This is mainly due to confidentiality constraints, which prevented back checking. Taking into account unallocated sales, the total consumption of primary aggregates in England and Wales was about 176.5 Mt in 2005.

To calculate UK totals data for Scotland was collected from Scottish Government (2007).

Table 42 Scottish Aggregates Survey, 2007

Scottish Aggregates (crushed rock, sand and gravel)	**Million Tonnes**
Total consumed in Scotland	23,970
Total exported to England	1,928
Total exported to outside GB	3,566

The combination of the two sources gave a total of **199,500 Kt which was used in calculations.** This was allocated to sectors in based on the following end uses:

Table 43 Aggregate End Use. Source: DCLG (2005)

Primary sales by end use, 2005	**%**	**Relevant Sector in Model**	
Coarse/fine concrete aggregate	36	88	Construction
Building/asphalting sand	6		
Roadstone/gravel, coated for asphalt	10		
Roadstone, uncoated	12		
Railway ballast	1		
Armourstone and gabion stone	0		
Other construction uses, including fill	16		
Undifferentiated aggregate use	6	49 52 53 88	Glass and glass products Cement, lime and plaster Articles of concrete, stone etc Construction
Other screened and graded aggregates	11	49 52	Glass and glass products Cement, lime and plaster
		53	Articles of concrete, stone etc
		88	Construction

Table 44 PRODCOM ONS data, 2008.

Gypsum and Plaster Products

Gypsum and anhydrite	Prodcom Sales	Intra EU Exports	Intra EU Imports	Extra EU Exports	Extra EU Imports	Prod-Export+Imps
Kt	Suppressed data	0.31	111	1	29	139

The report by WRAP - Review of Plasterboard Material Flows and Barriers to Greater Use of Recycled Plasterboard, 2006 provided a detailed analysis into gypsum in the UK for 2004. Due to the uncertainty and suppressed data from the PRODCOM download it was decided to use the following data from the WRAP report:

Table 45 Gypsum consumption. Source: WRAP (2006) extracted from Table 9.

	Mass in Mt 2004
Natural gypsum (UK mined)	1.7
Synthetic gypsum (UK produced)	1.9
Net imports	1.0 –1.5
Totals	**4.6 – 5.1**

The mid-range estimate of 4.85 Mt (4850 Kt) was used as the baseline for 2004. This was allocated to sectors in based on the following end uses:

Table 46 Gypsum and Plaster End Use. Source: WRAP (2006)

Relevant Sector		**%**
88	Construction	88
52	Cement, lime and plaster	12

Waste & Resources
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