HM Government

Unlocking Resource Efficiency

Phase 1 Executive Summary

DESNZ Research Paper Series Number 2023/039

November 2023

Any enquiries regarding this publication should be sent to us at: Resource_efficiency@energysecurity.gov.uk

Contents

List of Tables

List of Figures

1. Introduction

The Department for Energy Security and Net Zero commissioned a research project to explore the potential benefits from increasing resource efficiency across UK industry. This research was carried out in collaboration with the Department for Environment, Food & Rural Affairs. The results of this research are presented in this report and the accompanying sectors-specific reports. A detailed description of the methodology can be found in the methodological annex.

This report has six main sections:

- Section 1: Introduction, covering the research purpose, research objectives and key definitions;
- Sections 2 to 5: The key research findings for the Phase 1 of the research for each sector (cement & concrete, construction, steel and vehicles); and
- Section 6: Key cross-sector research findings and conclusions of Phase 1.

More detail about the research findings for each sector, including information on all the resource efficiency measures identified, a discussion of the drivers and barriers for these measures, and estimates for the current, maximum and business as usual (BAU) levels of efficiency for these measures, can be found in the four sector-specific reports which accompany this executive summary.

It is important to note that the sector-specific reports do not contain a detailed description of the methodology, and it is useful to have read this report and the methodological annex to understand how the conclusions have been drawn for each sector.

1.1 Background and policy context

For the purpose of this project, resource efficiency has been defined as the optimisation of resource use so that a given level of final consumption can be met with fewer resources. This can occur at production, consumption, or end of product life.

Examples of resource efficiency measures therefore include making lighter products (like making lighter/smaller cars), using recycled materials in production (such as recycled steel, recycled plastic), product sharing (like car clubs, clothing rental) and improving product lifespan (such as increased product reuse, improved product repairability).

As resource efficiency can reduce demand for raw materials, reduce energy demand and carbon emissions from industrial production, and reduce residual waste, it has a key role to play in many of the government's environmental and climate ambitions.

For example, resource efficiency plays a critical role in the government's plan to decarbonise industry, as well as meet their legally binding net zero target. This is evident in the Industrial Decarbonisation Strategy[1] (which sets out how industry will decarbonise to achieve net zero)

[1] BEIS (2021), Industrial Decarbonisation Strategy

where resource efficiency is currently projected to deliver 8 $MtCO_2e$ of industrial carbon savings per year by 2035.

Resource efficiency also has a key role to play in the government's Resources and Waste Strategy for England[2] and its ambition to maximise the value of resource use and minimise waste and its impact on the environment. This includes commitments to double resource productivity and achieve zero avoidable waste, both by 2050.

1.2 Research purpose and research objectives

There are currently substantial gaps in the evidence base which are impeding the development of evidence-based policies to deliver increased resource efficiency across the UK. The purpose of this research was to fill key gaps in the resource efficiency evidence base to inform the UK government's ambition on resource efficiency and support the development of future resource efficiency policy.

The research had four key objectives:

1) Identify a comprehensive list of resource efficiency measures across different industrial sectors;
2) Identify current and anticipated drivers and barriers which are affecting improvements in the identified resource efficiency measures, and their relative importance;
3) Build evidence-based estimates for the current "level of efficiency" and maximum "level of efficiency" in 2035 for each of the identified resource efficiency measures; and
4) Evaluate the extent to which industry is currently improving resource efficiency and build consensus estimates for the likely "levels of efficiency" in 2035, given current private sector incentives and the existing policy mix (a "business-as-usual" scenario), for each of the identified resource efficiency measures.

1.3 Research scope and definitions

1.3.1 Defining resource efficiency measures

For the purpose of this study, a resource efficiency measure has been defined as:

> *A measure that achieves a lower level of resource use for a given level of final consumption.*

Measures that meet the above definition are diverse and occur at all lifecycle stages, including production, consumption and end-of-product life.

While material substitution may not always meet the definition or resource efficiency set out above, it is considered to be in scope of this research, and has been defined as:

---

[2] Defra (2018), Resources and Waste Strategy for England

> *‘a measure that replaces some or all of a material used in production, where this reduces the whole life carbon of the final product’*

For the purposes of the study, the term ‘resource efficiency’ was used to refer to both resource efficiency and material substitution measures.

Resource efficiency measures were considered to be in scope if they could be impacted by UK action. The action could be at any stage of the value chain (including design, manufacture, use, end-of-life).

Throughout this research, a range of actions were identified that are not themselves resource efficiency measures (they do not directly reduce resource use on their own), but support the delivery of resource efficiency measures. For the purposes of this study these actions were called ‘enablers’.

1.3.2 Barriers and drivers

For each measure, barriers and drivers were identified. A barrier has been defined as anything that would prevent or reduce improvements in resource efficiency, and a driver has been defined as anything which would encourage or increase improvements in resource efficiency.

These drivers and barriers were categorised using two separate systems:

- The **PESTLE framework** which is focused on the types of changes: political, economic, social, technological, legal and environmental;
- The **COM-B framework** which is focused on behaviour change:
    - Capability: can this behaviour be accomplished in practice?
        - Physical Capability – e.g., measure may not be compatible for certain processes
        - Psychological Capability – e.g., lack of knowledge
    - Opportunity: is there sufficient opportunity for the behaviour to occur?
        - Physical Opportunity: e.g., bad timing, lack of capital
        - Social Opportunity: e.g., not the norm amongst the competition
    - Motivation: is there sufficient motivation for the behaviour to occur?
        - Reflective motivation: e.g., inability to understand the costs and benefits,
        - Automatic motivation: e.g., lack of interest from customers, greater priorities

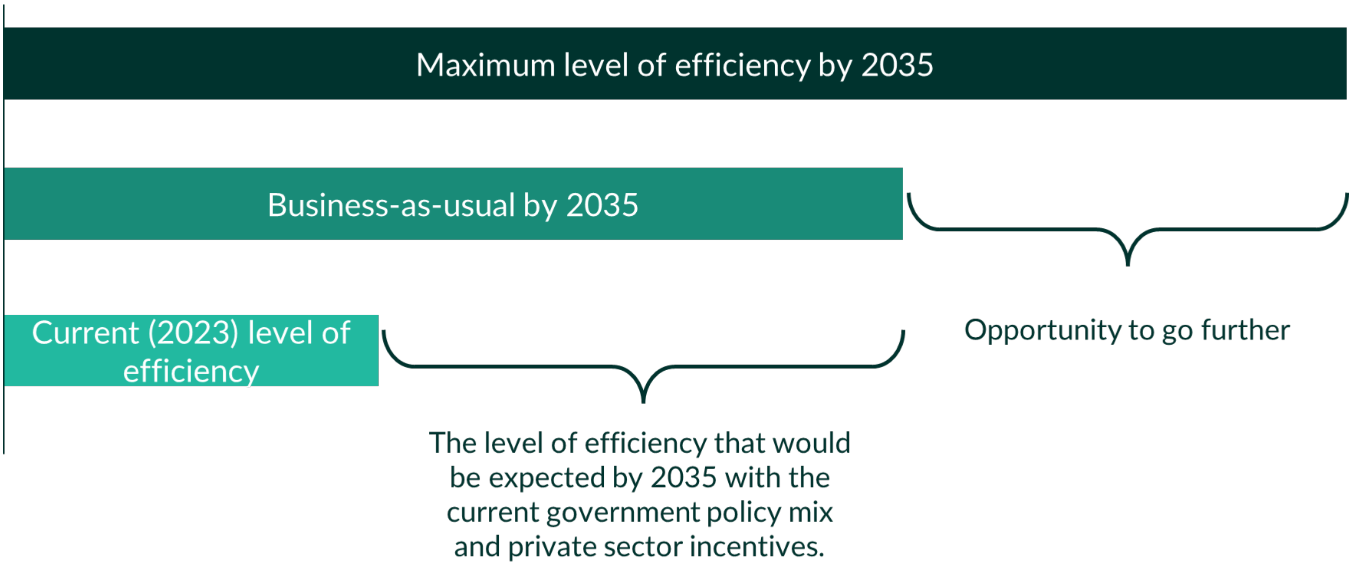
1.3.3 Defining levels of efficiency

As set out in the research objectives, one of the key objectives of this research was to build consensus estimates for three “levels of efficiency” for each of the identified resource efficiency measures. These were:

- The **current level of efficiency**, which is the best estimate for the current level of the measure, meaning what is happening in UK industry/with UK consumers at the time of this research in 2023;
- The **maximum level of efficiency** which is the maximum level of efficiency that is technically possible by 2035 in the UK, without factoring in potential barriers that could be overcome by 2035, meaning irrespective of economic (or other) barriers, the maximum level that could be achieved; and
- The **business-as-usual level of efficiency** which is the level of efficiency that would be expected in the UK by 2035 with the current policy mix and private sector incentives, meaning what would happen if there were no substantial changes for the policy or private sector environment.

An illustrative example of these three levels of efficiency is shown in Figure 1.

Figure 1: Illustrative example of the levels of efficiency for a resource efficiency measure



The gap between the BAU and the maximum levels of efficiency represents the opportunity for the sector to improve resource efficiency. The drivers and barriers help explain the differences between the three values.

It was expected that the BAU level of efficiency by 2035 would generally be higher than the current level of efficiency and lower than the maximum level of efficiency. However, it could also be possible that for certain measures the BAU level of efficiency in 2035 would be lower than the current level if the direction of travel of the measure is moving away from the maximum level of efficiency.

The level of efficiency estimates have been calculated for each measure independently. As there are substantial interactions between measures it should not be assumed that these levels of efficiency are additive or could all happen in parallel. More detail about the interdependencies between measures can be found in the accompanying sector-specific reports.

To estimate these levels of efficiency an indicator has been developed for each of the identified measures. These indicators have been chosen based on how well they capture the impact of the relevant measure, and how much data there is available on this basis (both in the literature review and from expert stakeholders). The purpose of the indicators in this research was so estimates on the current, maximum and BAU level of efficiency can be developed on a consistent basis. They were not intended to be used as metrics to monitor the progress of these resource efficiency measures over time, or to be used as metrics for resource efficiency policies.

It should be noted that for many measures with indicators that are a percentage reduction, where a robust data has not been available to produce a baseline the current level of efficiency has been set a 0% - setting the current year (2023) as the baseline in which the maximum and BAU levels of efficiency will improve upon.

1.3.4 Sector selection

As resource efficiency measures and their associated barriers and drivers differ substantially between industrial sectors, this research has been conducted at the sector level.

Eleven sectors have been selected for this research, which was divided in two phases:

- Phase 1: cement & concrete, construction, steel and vehicles; and
- Phase 2: chemicals, food & drink, electricals, glass, paper, textiles and plastic.

These sectors have been chosen by DESNZ in collaboration with Defra because they have high potential for carbon reduction, virgin material reduction and waste prevention, which are departmental priorities.

This report and the accompanying sector-specific reports cover the research conducted in Phase 1 only. The details of Phase 2 of this research are covered in the Phase 2 Executive summary and the accompanying sector-specific reports which will be published when that research has been completed in 2024.

The 11 selected sectors for this research project are not homogenous. While some have material outputs (chemicals, steel, paper, plastics, glass, cement and concrete), others have product outputs (vehicles, textiles, electricals, construction, food and drink). This creates a situation of dependencies between the research sectors, where resource efficiency measures that apply to an upstream sector naturally apply to the downstream sector, and vice versa. Table 1 shows a high-level mapping of the sectors and their upstream and downstream dependencies.

Table 1: Mapping of sector relationships

Phase	Sector type	Upstream sector dependencies	Sector	Downstream sector impacts
Phase 1	Material		**Cement & Concrete**	Construction
Phase 1	Product	Steel, Cement & Concrete, Glass	**Construction**	
Phase 1	Material		**Steel**	Construction, Vehicles
Phase 1	Product	Steel, Plastics, Textiles, Electricals	**Vehicles**	
Phase 1	Product	Plastics	**Textiles**	Vehicles
Phase 2	Product	Chemicals	**Food & Drink**	
Phase 2	Product	Steel, Plastics, (Glass)	**Electricals**	Vehicles
Phase 2	Material	Chemicals	**Glass**	Construction, (Electricals)
Phase 2	Material	Chemicals	**Paper**	
Phase 2	Material		**Chemicals**	Food & Drink, Construction, Glass, Paper, Plastics
Phase 2	Material	Chemicals	**Plastics**	Vehicles, Electricals, Textiles

2. Cement & Concrete

This section summarises the key findings regarding the list of resource efficiency measures, the top drivers and barriers for each measure, and the levels of efficiency (and associated evidence RAG ratings) for the cement and concrete sector. The complete findings are presented in the Unlocking Resource Efficiency: Phase 1 Cement and Concrete Report.

2.1 Sector introduction

Cement and concrete are closely related materials used in construction that play crucial roles in building infrastructure.

Cement is a fine powder made primarily from limestone, clay and other minerals, which undergoes a chemical reaction when mixed with water to form a paste which acts as a binder. The manufacture of cement can be split into two main stages. First, the raw materials are combined and exposed to high temperatures in a rotating kiln. This causes a chemical reaction which produces clinker and directly releases carbon emissions. This is the most emissions intensive part of the process, accounting for 94% of total emissions from cement manufacturing[3]. The clinker is then cooled and ground into a fine powder which is mixed with a small amount of gypsum to form cement. There are different classifications of cement depending on the mix of input materials. A list of cement grades can be found in Appendix E. Cement is mainly used as a binder in concrete but can also be used as a component of mortar, stucco, tile grout or thin-set adhesive.

By contrast, concrete is a composite material formed by mixing cement with aggregates like sand, gravel or crushed stone and water. Clinker is the most emissions intensive ingredient in concrete, accounting for 89% of embedded emissions. The aggregates provide strength and stability to the concrete, while the cement paste acts as a binding agent, holding the aggregates together. Concrete is versatile, durable, and widely used in the construction industry for building foundations, walls, floors and various other structural elements.

Cement and concrete both play a vital role in the UK economy. The construction industry relies heavily on these materials for infrastructure development, including residential, commercial and public projects. In 2021, 15.6 million tonnes of cementitious materials were sold in the UK and over 90 million tonnes of concrete are consumed each year, produced from around 1,000 sites nationwide[4]. Mineral products, including cement and concrete, contribute about £18bn to the UK's GDP, and directly employing 74,000 people while supporting a further 3.5m jobs in 2020.[5] The cement and concrete industries also support a network of related sectors such as mining, transportation, equipment manufacturing and engineering services. These sectors supply raw materials, transport finished products and provide expertise for construction projects, further enhancing economic activity and employment opportunities.

Resource efficiency in the cement and concrete sectors focuses on optimising the use of materials throughout the entire lifecycle of cement and concrete production. Cement production requires significant amounts of raw materials, and these must be carefully selected

[3] Material Economics (2019). Industrial Transformation 2050. Accessed at link.
[4] MPA (2021) 'Profile of the UK Mineral Products Industry' supporting statistics workbook
[5] MPA (2020). UK Concrete and Cement Industry Roadmap to Beyond Net Zero.

and proportioned to minimise waste. Additionally, cement and concrete production generate various waste materials from the cement manufacturing process. Cement also makes up a significant amount of construction and demolition waste. Waste can be managed using effective practices such as recycling and reusing materials. For example, crushed concrete can be used as recycled aggregate in new concrete mixes, reducing the need for virgin aggregates. Additionally, by-products like fly ash and slag from other industries can be utilised as supplementary cementitious materials, further reducing resource consumption outside the sector. Resource efficiency also encompasses optimising the design of concrete products to enhance their durability whilst minimising the use of resources.

Efficient use of resources can also reduce the sectors environmental footprint, reducing raw material consumption, energy consumption and associated greenhouse gas emissions. Cement and concrete manufacturing is currently very carbon intensive, emitting 7.3 $MtCO_2e$ in 2018, approximately 1.5% of the UK's greenhouse gas emissions.[6] The carbon intensity of cement production is due to the chemical reactions required to produce clinker (which emit carbon dioxide directly), and the high temperatures required which is traditionally achieved through the burning of fossil fuels. Resource efficiency measures help reduce the overall environmental impact by optimising material usage, minimising waste generation and conserving energy.

Using resource more efficiently can also results in cost savings through a reduction in raw material use, and a switch to potentially cheaper alternative materials. The cement and concrete sectors are resource-intensive industries, and any wastage or inefficiency in material usage can result in significant financial losses. By adopting resource-efficient practices such as optimising raw material consumption, recycling waste materials and switching to alternative input materials, these sectors can reduce costs and enhance their competitiveness.

Sector scope

The scope of this report covers resource efficiency measures for Portland cement (CEM I) for use as a binder within concrete. This application was selected because the vast majority of cement is used in concrete production, and as a result improvements in cement use within the concrete sector has the largest potential for impact and also the greatest availability of information within the literature.

The following topics are out of scope in this study:

- Non-concrete applications of cement: Although most cement is used in concrete, cement can also be used for other applications such as mortar (which is used for joining bricks, stones and other masonry materials) and grout (used for filling voids, cracks and gaps in structures to provide structural support and prevent water leakage). Cement is also used for soil stabilisation in road construction to enhance the load-bearing capacity and stability of the soil.
- Niche cements: This refers to innovative types of cement that differ from CEM I in terms of their composition or manufacturing process with the aim of addressing specific challenges or offering improved performance. Examples of niche cements not included within this study are cements based on magnesium oxide derived from carbonates or silicates, CSA-belite cements, cement based on municipal solid waste incinerator ash and thermoplastic carbon-based cements. These alternatives occupy

[6] MPA (2020). Net Zero Carbon. Accessed at link.

niche positions in the market, are not yet feasible for use and according to stakeholder comments are unlikely to be ready at scale by 2035.

- Alternative fuels and energy efficiency: The cement industry is energy-intensive, with a significant portion of energy consumption (around 50%) coming from fossil fuels. Some environmental initiatives focus on reducing energy consumption and carbon emissions through alternative fuels such as biomass, waste-derived fuels, or non-recyclable plastics or energy-efficient technologies like advanced kiln designs, waste heat recovery systems, and optimised process control. These are not considered to be resource efficiency measures and so are out of scope of this study. Deep decarbonisation strategies such as carbon capture, utilisation and storage (CCUS) are also considered out of scope.

- Water consumption: Water is a vital resource in cement and concrete production, used for cooling kilns, mixing concrete and curing. Some resource efficiency measures aim to minimise water usage through the adoption of water-efficient technologies, recycling process water, and implementing water management strategies. Techniques like dry process kilns, closed-loop water systems and rainwater harvesting help reduce water consumption and ensure sustainable water use. Water consumption is out of scope as this study focuses only on the efficiency of cement and excludes other resources such as water.

- Concrete durability: Resource efficiency also encompasses optimising the properties and performance of cement and concrete products to enhance their durability and lifespan. Durable concrete structures require fewer repairs and replacements, reducing resource consumption over time. This includes using high-quality materials and considering long-term maintenance and lifecycle costs. Measures that relate to concrete durability are included in this study but are presented in the Unlocking Resource Efficiency: Phase 1 Construction Report.

2.2 List of resource efficiency measures

Table 2 shows the resource efficiency measures identified for the cement and concrete sector.

Table 2: List of resource efficiency measures for the cement & concrete sector

#	Lifecycle stage	Strategy	Measure name	Measure indicator
1	Design	Material substitution	Portland cement (CEM I) intensity in concrete	CEM I-to-concrete ratio
2	Manufacture and assembly	Reducing waste	Portland cement (CEM I) manufacturing waste recovered as raw material	% of CKD waste recovered and used as cement manufacturing raw material feedstock
3	Design	Use of secondary raw materials	Use of recycled concrete fines in cement or concrete production	% concrete fines used in cement or concrete production

#	Lifecycle stage	Strategy	Measure name	Measure indicator
4	Design	Light weighting	Lean design of concrete structures	% reduction in concrete demand for the same unit throughput relative to 2023
5	Manufacture and assembly	Reducing waste	Waste reduction in concrete manufacturing	% of concrete wasted per $100m^3$ of concrete manufactured
6	Design	Use of secondary raw materials	Use of recycled content in concrete	% recycled concrete aggregates used in concrete by mass

Most of the identified resource efficiency measures take place in the design phase of the lifecycle. This is because cement is transformed into concrete during the use phase of the lifecycle, which is subsequently used as part of the building / infrastructure. These measures are therefore included in the construction sector.

The two measures that are not part of the design phase, Measures 2 and 5, refer to cement or concrete waste at different stages of the supply chain.

2.3 Drivers & Barriers

Throughout the research, a range of drivers and barriers were identified for each of the measures. The most important ones are listed in Table 3.

Table 3: Top drivers and barriers for the cement and concrete measures

#	Measure name	Top drivers	Top barriers
1	Portland cement (CEM I) intensity in concrete	Some substitutes are widely available. Some substitutes are cheaper. Climate policy driving carbon reductions.	Some substitutes are not widely available. Some substitutes are more expensive. Lack of testing and industry experience.
2	Portland cement (CEM I) manufacturing waste recovered as raw material	Cost savings due to reduced raw material requirements.	Market concerns about cement performance. Lack of cost-effective technology to return dust to the kiln system.
3	Use of recycled concrete fines in cement or concrete production	Cost savings due to reduced energy use.	Quality of concrete fines and potential contamination. Cost of collection and demolition. Lack of regulation, standards and guidelines.

#	Measure name	Top drivers	Top barriers
4	Lean design of concrete structures	Climate policy driving carbon reductions.	Cost of construction for lean design. Industry culture and unwillingness to adopt unfamiliar materials and construction methods.
5	Waste reduction in concrete manufacturing	Cost increase of cement and concrete. Client reporting requirements.	Over-ordering / cost of under-ordering. Push to construct as fast as possible.
6	Use of recycled content in concrete	Client requirements for recycled content.	Availability of supply, and quality of the coarse recycled concrete aggregate (CRCA).

Cost savings and/or cost increases of raw materials are a common top driver, as the industry is very price-sensitive with small margins and low product differentiation. On the other hand, cost also appears frequently as a barrier, especially in terms of additional costs required by the implementation of some resource efficiency measures.

Regarding measure 1, the barriers and drivers are highly dependent on the materials that are being substituted. This is evidenced by the fact that substitute availability and price appear both in the drivers and barriers section. For example, limestone is widely available, while granulated blast-furnace slag and pulverised fly ash are already highly utilised and availability is expected to decrease over time, as the steel industry and the power sector decarbonise.

Finally, since cement and concrete are part of the construction value chain, the downstream requirements or preferences from construction companies and/or final clients can be top drivers of the adoption of these measures, or key barriers.

2.4 Levels of efficiency

Table 4 provides a summary of the levels of efficiency (and the evidence RAG rating in italics) for the six identified measures of the cement and concrete sector.

Table 4: Levels of efficiency and evidence RAG rating (*in italics*) for cement and concrete measures

#	Measure name	Indicator	Current	Maximum in 2035	Business-as-usual in 2035
1	Portland cement (CEM I) intensity in concrete	CEM I-to-concrete ratio	70-82% *Amber-Green*	45 – 55% *Amber-Green*	50 – 60% *Amber*
2	Portland cement (CEM I) manufacturing waste recovered as raw material	% of CKD waste recovered and used as cement manufacturing raw material feedstock	3.7% *Amber-Green*	60 – 70% *Red*	<5% *Red*

#	Measure name	Indicator	Current	Maximum in 2035	Business-as-usual in 2035
3	Use of recycled concrete fines in cement or concrete production	% of concrete fines used in cement or concrete production	0 – 1 % *Amber*	16 – 30% *Red-Amber*	1 – 5% *Amber*
4	Lean design of concrete structures	% reduction in concrete demand for the same unit throughput relative to 2023	0% *N/A*	26 – 35% *Amber*	5 – 15% *Red-Amber*
5	Waste reduction in concrete manufacturing	% of concrete wasted per $100m^3$ of concrete manufactured	2.5 – 7.5% *Amber-Green*	1 – 5% *Amber*	1 – 5% *Red-Amber*
6	Use of recycled content in concrete	% recycled concrete aggregates used in concrete by mass	0-5% *Red-Amber*	20-50% *Red-Amber*	0-5% *Red-Amber*

General insights

Across almost all of the measures identified in the cement and concrete sector, the BAU level of efficiency was higher than the current level of efficiency (or lower where the measure is about waste reduction – Measure 5) suggesting that the level of efficiency is expected to improve in the current environment. A key driver of this, which is common across all measures, is the drive to decarbonise and the carbon savings benefits that resource efficiency measures can deliver.

The exception to this trend is Measure 6 (and to some extent Measure 3) where the current level of efficiency is the same or similar to the BAU level of efficiency. This is because these measures require technological innovation and the large-scale adoption of new technology such as extraction and sorting of concrete waste) and so are not expected to occur without a substantial change in the market environment.

Similarly, across almost all measures identified in the cement and concrete sector, the BAU level of efficiency was lower than the maximum level of efficiency (or higher where the measure is about waste reduction – Measure 5), suggesting the full resource efficiency potential will not be achieved without a change in the market environment. There are a range of barriers which limit the uptake of measures, but a key one common across multiple measures are the increased costs associated with some measures, and concerns about the performance of cement/concrete produced by alternative methods. The one measure in the sector where the BAU level of efficiency is the same as the maximum level of efficiency is Measure 5. This is because waste reduction has been at the forefront of the industry sustainability agenda for decades and so substantial progress has already been made (meaning less change is needed to reach the maximum level of efficiency, and the industry is knowledgeable about the changes needed), and because waste reduction has a clear financial benefit.

Measure-specific insights

Measure 1 was identified by the cement stakeholders as having the most potential for resource efficiency and shows that CEM I intensity in concrete has been decreasing over the past decade and is expected to decrease further without further intervention. This decrease is driven by decarbonisation and the lower cost of some substitutes. While decrease is expected, it will not fully reach the maximum level of efficiency with the current mix of incentives and policies of the BAU scenario. The barriers include concerns about strength, lack of standards for novel SCMs and that substitutes may be limited to use in certain applications.

Measures 2, 3, and 6 deal with the recovery and recycling of cement and concrete, but in different parts of the value chain. In all three cases, the estimates for the BAU are very close to the current level of efficiency, and far from the maximum level of efficiency. These measures have significant barriers (e.g., requiring the investment in new equipment, technical and physical limitations), that prevents wider uptake of these measures. Likely because of these significant barriers and the resulting uncertainty about the potential for these measures, the evidence RAG ratings for these measures were poor compared to other measures.

Finally, Measures 4 and 5 are related to the concrete manufacturing and use parts of the value chain, usually on construction sites. Both measures show the BAU halfway through the current and maximum level, suggesting an increase in resource efficiency is expected but resource efficiency potential will not be maximised in the current environment. One of the key drivers for these measures is the desire by businesses to decarbonise. However, there are still substantial barriers such as the need for materials to always be available on construction sites (Measure 5) and the increased design costs needed for lean design (Measure 4).

3. Construction

This section summarises the key findings regarding the list of resource efficiency measures, the top drivers and barriers for each measure and the levels of efficiency (and associated evidence RAG ratings) for the construction sector. The complete findings are presented in the accompanying report 'Construction Resource Efficiency Measures'.

3.1 Sector introduction

The construction sector is an important element of the UK economy, with output accounting for 7% of the UK's GDP.[7] Breaking down the UK construction sector into sub-sectors, the ONS data presents two broad areas of work: new construction and repair and maintenance.[8] Data from 2021 showed that of all work in the UK sector, new construction contributed to 74% of the sector's economic output, with repair and maintenance at 26%.[9] Within the broad areas are various further sub-sectors. These include housing, commercial and infrastructure. Each sub-sector, except for infrastructure, can also be classified as either public or private sector. In 2021, private new housing was the largest new build sub-sector by value, at 22% of overall work.[10]

The statistics provided in the ONS documents cited above are for any activity falling under Category F of the UK SIC code system.[11] This also includes subcontracting of work. The category excludes the manufacturing of construction products, which is classified in Section C. It also excludes the contracting of services for engineering design work, which is classified under Category M. The key difference between contracting and construction projects is the scope of work undertaken. For contracting projects, the contracting body will manage the broad process of designing, acquiring, managing, and executing the building of a structure. Construction by contrast relates to just the managing and executing part of building a structure. Throughout this work there is reference to both construction and contracting activities.

The construction sector has a broad and complex landscape of stakeholders. Each stakeholder will have varying involvement across a construction project lifecycle. This project may be related to any of the sub-sectors outlined previously. The project lifecycle includes stages design, construction process, use and end of life. Stakeholders that may be involved in these stages are architects, planning authorities, engineers, contractors, insurers and material suppliers. Each of these stakeholders are fed into three main skill sectors: contracting, services and products. This complex stakeholder landscape makes construction a high-cost, high-risk and long-term activity.[12]

Given the activities and size of the sector, the environmental impacts of the sector are substantial. Activity within the built environment is responsible for 25% of UK greenhouse gas emissions, excluding surface transport.[13] Engineering and construction is also the world's largest consumer of raw materials, taking in 3bn tonnes of raw materials and 50% of steel

[7] ONS (2023) Construction output in Great Britain: April 2023. Available at: link
[8] ONS (2023) Output in the construction industry: sub-national and sub-sector. Available at: link
[9] Ibid
[10] Ibid
[11] Office for National Statistics (2022) UK SIC 2007. Available at: link
[12] Designing Buildings (2022) UK Construction Industry. Available at: link
[13] UKGBC (2021) Whole Life Carbon Roadmap – A pathway to net zero. Technical Report. Available at: link

production.[14] Examining the downstream impacts, the UK generated 222.2m tonnes of waste in 2018, of which, 137.8m tonnes (62%) was generated by construction, demolition and excavation activities.[15]

Resource efficiency has been identified as an opportunity for the construction sector to reduce its environmental impact. From the supply side, material substitution and efficiency production processes to reduce wastage could reduce total materials required, and the associated emissions, energy use and waste generated. With the demand side, design strategies which include a reduction in overdesign and leaner construction could be deployed to reduce raw material demand, and the associated emissions, energy use and waste generated.

This report will outline measures to achieve resource efficiencies in the UK construction sector and the barriers and drivers in achieving them.

Sector scope

The scope of this report covers the resource efficiency of the construction of projects within the UK. There is consideration of design elements which are concerned with contracting activities undertaken that enable the delivery of actual construction. Within scope also sit the construction sub-sectors of housing, infrastructure and commercial. Each sub-sector is then further categorised by public and private as well as new and repair and maintenance.

The following areas are out of scope of this study:

- Operational emissions – operational emissions are those generated during a building's use phase. These emissions may originate from heating, cooling, ventilation, lighting and water use. Some of the resource efficiency measures found in literature discussed how to minimise operational emissions. This reduction might be achieved by using certain insulation materials for example.
- Specific materials – construction projects across all construction sub-sectors rely on an array of material types. Notable examples of materials used in construction include concrete & cement, steel and glass. Resource efficiencies which relate specifically to these materials can be found in their individual sector reports and are out of scope for this report. What is in scope for the construction sector is the resource efficiency use of these materials in context of the construction industry.

3.2 List of resource efficiency measures

Six measures were identified for the construction sector: three in the design lifecycle stage, one at assembly, one in the use stage and one at the end of life.

[14] ARUP (2016) Circular Economy in the Built Environment. Available at: link
[15] DEFRA (2018) Official Statistics: UK Statistics on waste. Available at: link

Table 5: List of resource efficiency measures for the construction sector

#	Lifecycle stage	Strategy	Measure name	Measure indicator
1	Design	Use of secondary raw materials	Use of reused content in buildings	% reused content used in buildings by mass
2	Design	Material substitution	Use of material substitution for embodied carbon reduction across the whole lifecycle of a building	% CO_2e reduction in embodied carbon for the entire lifecycle associated with material substitution
3	Design	Light-weighting	Reduction of over-design & delivery in building structures	% reduction in material mass in construction relative to 2023 levels
4	Manufacture and Assembly	Reduction in production wastes	Reduction of construction process wastage	% of total construction materials wasted by mass
5	Use	Lifetime extension	Reducing need for primary material production through repurposing/repair of the existing building stock	The % change of new builds avoided by repair/refurbishment of the existing building stock relative to 2023 levels
6	End of Life	Recycling and Reuse	Recovery of building materials for reuse / recycling	% of avoidable C&D waste recovered for reuse / recycling

These measures apply to all the construction products, but the level of their application may vary by material type, or by construction sub-sector. For example, under Measure 1, structural steel can be more easily reused than other elements (e.g., plasterboard), and under Measure 5, it is much easier to repair/repurpose the existing housing/commercial building stock to reduce the need for new construction, than it is for infrastructure (as new infrastructure projects will tend to have a different purpose).

3.3 Drivers & Barriers

Through the research, a range of drivers and barriers were identified for each of the measures. The most important ones are identified in Table 6.

Table 6: Top drivers and barriers for the construction measures

#	Measure name	Top drivers	Top barriers
1	Use of reused content in buildings	Opportunity to develop a market around reused products. Environmental benefits: reduction of raw material	Lack of consistent supply of reused products or components. Limited data availability on the location, quality and quantity of reusable components in the existing building stock. Lack of certification instruments.

#	Measure name	Top drivers	Top barriers
		requirements and reduction of embodied carbon.	
2	Use of materials substitution for embodied carbon reduction across the whole lifecycle	Increased uptake of whole life carbon assessment (WLCA) for construction projects. Reducing emissions.	Volatile demand economics for alternative materials. Higher cost of alternative materials.
3	Reduction of over-design and delivery in building structures	Reduction in use of virgin and /or recycled materials and/or decarbonisation trend. Increased uptake of Building Information Modelling (BIM) and design code changes. Promotion of the waste hierarchy.	Additional design & testing work is more expensive than material savings. Need for benchmarks for designers and review of the construction codes to eliminate prescriptive requirements that drive over-design (i.e. live load). Technological confidence required to reduce factors of efficiency (applies to manufacturing processes and certification schemes).
4	Reduction of construction process wastage	Measurement of process waste (e.g., corporate reporting requirements). Higher cost and workflow predictability of IHC methods. Uptake of digital technologies to predict, monitor and characterise of waste.	Lack of collaboration within the supply chain. Need for higher levels of skills and education about waste minimisation. Waste measurement: Difficulty in calculating waste rates and getting accurate information.
5	Reducing need for primary material production through repurposing/repair of the existing building stock	Savings associated with undertaking retrofit, renovation or repair, relative to the costs of demolishing and subsequent new builds. Shifts in citizen attitudes away from the perception that new is better.	20% VAT on retrofit, refurbishment and renovation but new build has 0%. Cost of design of future retrofit.
6	Recovery of building materials for reuse/recycling	Economic benefits from the reuse and recycling.	Lack of sorting, testing and storing facilities for materials. Current waste reporting methods and requirements. Market not favourable to reuse. Regulatory framework. Lack of data on the product properties and specifications entering the waste stream.

The construction sector is generally price-sensitive and cost appears in several cases as either a driver or a barrier. Cost is both a driver and a barrier of action on resource efficiency because different measures have different cost implications, both in terms of whether prices increase or decrease, and where in the value chain these price changes are felt. For example, for Measures 1, 2, 3 and 5 costs decrease due to a reduction in the cost of raw materials, whereas for Measures 4 and 6 costs decrease due to a reduction in waste management costs. Conversely for Measures 3 and 5 costs may in some cases increase due to increased design time. Cost as a barrier/driver to resource efficiency action is discussed in more detail in Section 7.2.

3.4 Levels of efficiency

Table 7 provides a summary of the levels of efficiency (and the evidence RAG rating in italics) for the six identified measures, although Measure 6 is split into two separate indicators for reuse and recycling. Three of the measures have indicators of 'reduction of' and have been baselined to 0% for the current level (2023): Measure 2, Measure 3 and Measure 5.

Table 7: Levels of efficiency and evidence RAG rating (*in italics*) for construction measures

#	Measure name	Indicator	Current	Maximum	Business-as-usual
1	Use of reused content in buildings	% reused content used in building by mass	< 5% *Red-Amber*	11 – 20% *Red-Amber*	5 –- 15% *Red*
2	Use of materials substitution for embodied carbon reduction across the whole lifecycle	% CO_2 reduction in embodied carbon for the entire lifecycle associated with material substitution	0% *N/A*	20 – 36% *Red*	0 – 20% *Red*
3	Reduction of over-design and delivery in building structures	% reduction in material mass in construction relative to 2023 levels	0% *N/A*	10 – 21% *Amber*	0 – 10% *Red-Amber*
4	Reduction of construction process wastage	% of total construction materials wasted by mass	10-15% *Green*	1 – 5% *Amber*	5 – 15% *Red-Amber*
5	Reducing need for primary material production through repurposing/repair of the existing building stock	% new builds avoided by repair/refurbishment of the existing building stock relative to 2023 levels	>0% *N/A*	>25% *Red-Amber*	4 – 14% *Red*
6	Reuse of building materials for reuse/recycling	% of C&D waste recovered for reuse	2 – 7% *Amber*	15 – 20% *Amber*	5% *Red*

#	Measure name	Indicator	Current	Maximum	Business-as-usual
	Recycling of building materials	% of C&D waste recovered for recycling	67 – 73% *Amber*	75 – 80% *Amber*	>85% *Red*

General insights

Across all of the measures, there is some improvement in resource efficiency expected through to 2035, as the BAU level of efficiency is higher than the current level (or lower when the measure is about waste reduction – Measure 4). A key driver of this improvement, common across all measures, is the drive to decarbonise and the carbon savings potential from resource efficiency action. In the construction section specifically, this is being driven by increased demand from consumers for lower-carbon products, and the increased uptake of whole life carbon assessment which is making the carbon saving benefits from resource efficiency more visible.

However, this level of improvement is some distance away from the maximum level for all measures. A key barrier to improvement, common across most measures, is the increased cost of resource efficiency. The reason for these increased costs varies for different measures, from increased time needed at the design stage (e.g., Measure 3 – reduction in overdesign and delivery) to increased testing needed to ensure reused/second-life materials and products have the same functionality as new ones (e.g., Measure 1 and Measure 6 – reuse of building materials/components).

Measure specific insights

One of the biggest gaps between maximum and BAU levels of efficiency was observed for Measure 2. This gap is explained by two factors. First, the rate at which substitutions were made. This measure found literature covering the potential greenhouse gas emissions which could be reduced by material substitution. What was not reported in the literature was the frequency at which the substitutions are made. The maximum level of efficiency covers the full range of carbon savings that are possible through a number of substitutions. The BAU scenario reflects that all of these substitutions are unlikely to take place in reality. Furthermore, there are a number of significant barriers to overcome. These barriers include structural changes relating to training of the workforce and volatile economics, which likely require lengthy periods of time.

Measure 2 does not lead to raw material savings *per se* but contributes to the decarbonisation of the sector through alternative material choices. This measure is being driven by the desire for lower carbon construction and use of WLCA. However, it is limited by higher and more volatile cost of alternative materials. This measure is deemed to have a large potential, however, given the diversity of materials and applications used in the construction sector, the evidence RAG ratings for the estimates of savings is low. Measure 2 was by far the most controversial for the construction sector stakeholders. Stakeholders were particularly concerned with how certain materials were presented in the context of the measure. The most important point stakeholders wished to be conveyed was that no one material was defined as ‘low carbon’ or ‘green’. Rather, taking a whole life carbon approach, each individual material selection would have a unique material that is the correct selection for a given role. This was reflected in how the measure was reported in the Unlocking Resource Efficiency: Phase 1 Construction Report.

Measure 5 also has a significant gap between maximum and BAU levels of efficiency. This measure has a significant number of barriers. Barriers include social perceptions on the attractiveness of retrofit, which will likely take significant time and efforts to change. Furthermore, many of the other barriers are regulatory, which also will take significant time and investment to overcome.

Measure 6 also has significant gaps between maximum and BAU levels of efficiency for both indicators. This measure again has a significant number of barriers. There is potential for the levels of efficiency to improve, but there must be infrastructure such as storing and sorting facilities put in place. Creation of this infrastructure will take time and this view is reflected in the gap between maximum and BAU levels of efficiency.

The measure with the smallest gap between maximum and BAU level of efficiency and thus most likely to be realised by 2035, is Measure 1. This implies that, as long as the material is supplied (covered in Measure 6 and assumed as a given for this measure), there will be a greater level of reused content in construction projects from 2035. It is anticipated this is due to potential for positive impacts of reused content on embodied carbon outputs. This will support construction projects in meeting the targets that are either being set by regulations or internal requirements.

A key point to note on unusual findings is the level of efficiency reported for the BAU and maximum levels of efficiency for both indicators in Measure 6. In all other scenarios, the BAU is lower. The reuse rate for the BAU scenario and the maximum level of efficiency drops significantly, due to the barriers associated with generating supply of reused material (through preparation for reuse). As such, the recycling rate must increase as the indicator is additive and sums to 100%.

Overall, the evidence RAG ratings for the maximum and BAU levels of efficiency for this sector tend to be amber or red-amber. This is due to the complexity of the construction sector and the need to utilise indicators that encompass a wide range of activity. Some stakeholders were familiar with datapoints only for specific materials (e.g., steel or timber), or for certain types of buildings (residential or commercial) and not the entire sector. Where available, this has been reflected in the Unlocking Resource Efficiency: Phase 1 Construction Report.

4. Steel

This section summarises the key findings regarding the list of resource efficiency measures, the top drivers and barriers for each measure and the levels of efficiency (and associated evidence RAG ratings) for the steel sector. The complete findings are presented in the Unlocking Resource Efficiency: Phase 1 Steel Report.

4.1 Sector introduction

The UK steel sector is large and economically significant. It employs 39,000 people in 1,135 businesses[16] and has an economic output of £2.4bn, making up 0.1% of the UK economy and 1.2% of manufacturing output.[17] Steel is a widely used material across the economy and is fundamental to the construction, automotive, defence and energy sectors.

There are two ways of making steel. Traditionally, mined iron ore is heated using coal and fossil fuels in a blast furnace, and then reacted with oxygen in a basic oxygen furnace (BF-BOF). Coke derived from coal is used as a reductant in the BF-BOF steel making process. An alternative process involves primarily melting of recycled scrap steel in an electric arc furnace (EAF). In the UK in 2021 7.2MT total of steel was produced with1.3MTpa from EAF and 5.9Mt from BF-BOF.

The purest form of steel has traditionally been from blast furnaces using virgin, uncontaminated ore. However, recent advances in EAF technology allows equivalent performance if feedstocks are tightly controlled for composition. EAFs typically reprocess scrap steel, from all sources, and the UK's imports of scrap are from known and established sources and so allow domestic (UK) EAFS to produce steel of reliable quality for construction and other mass markets.

Resource efficiency is a critical pathway that the steel sector can use to reduce its environmental impact, reducing raw material consumption, energy use, greenhouse gas emissions and waste generation. Using resources more efficiently can also result in cost savings through a reduction in raw material use, and a switch to potentially cheaper alternative materials.

Sector Scope

Resource efficiency measures in the steel sector focus on optimising the use of steel throughout the entire lifecycle. This covers:

- **Steelmaking – raw materials** – replacing fossil fuels used as reductants (coal, coke and natural gas) with non-fossil (e.g. biomass, plastics and rubber, green hydrogen).
- **Steelmaking – production** – primarily related to greater use of EAF (and therefore a greater use of scrap steel), but also relating to the reuse of steel-making byproducts.

[16] Keep, M.; Jozepa, I.; Ward, M.; (2023). Contribution of the steel industry to the UK economy. House of Commons Library Debate Pack.
[17] Keep, M.; Jozepa, I.; Ward, M.; (2023). Contribution of the steel industry to the UK economy. House of Commons Library Debate Pack.

- **Use of steel - products** – Light-weighting and lifespan extension of steel-based products.
- **Use of steel - end-of-life processes** – reusing, repairing, remanufacturing and recycling steel-based products.

The scope of this report covers resource efficiency measures for the steel sector as described above. To avoid duplication and double counting with other studies the following topics are out of scope of this study:

- Fuel switching: Fuel switching e.g. to hydrogen (H2DRI) is out of scope of this study. Fuel switching and energy efficiency are out of scope as these relate to carbon efficiencies and not steel resource efficiencies.
- Energy efficiency: This is not considered within this study as it is considered in other studies outside of this project.
- Steel used in other sectors: This includes steel used in the production of vehicles and in construction as these are considered separately in separate reports within this project.

4.2 List of resource efficiency measures

Table 8: List of measures for the steel sector

#	Lifecycle stage	Strategy	Measure name	Measure indicator
1	Design	Primary material substitution	Substitution of fossil-carbon reductant with waste-based alternatives	% reductant (in weight) replaced by plastic or rubber waste alternatives
2	Design	Primary material substitution	Substitution of fossil-carbon reductants through use of hydrogen to produce direct reduced iron in EAFs	% of UK crude steel produced using hydrogen-DRI-EAF
3	Design	Use of secondary raw materials	Transition from ore-based to scrap-based steel production	% of scrap per tonne of crude steel for BF-BOF and EAF in UK steel production
4	Manufacture	Shift to electric arc furnace	Transition from basic oxygen furnace to electric arc furnace steelmaking	% of UK crude steel produced using EAF
5	Manufacture	Process efficiencies	Recovery and utilisation of process off-gases	% reduction in carbon emissions % reduction in carbon inputs
6	Manufacture	Process efficiencies	Recovery and use of steelmaking by-product materials	% of steelmaking by-products recovered and used

#	Lifecycle stage	Strategy	Measure name	Measure indicator
7	Design	Light-weighting	Light-weighting and use of higher grades of steel in consumer products	% reduction in weight of consumer product
8	Use / EoL	Life extension / Reuse / remanufacture / recycling	Increased reuse, repair, remanufacture and recycling of steel-based products	% of reused steel in a product % of repaired steel in a product % of remanufactured steel in a product % of recycled steel in a product

The nine identified measures in the steel sector span across the whole value chain. At the start of the lifecycle in the design phase there are two measures (Measures 1, 2), relating to the primary material substitution of the fossil-carbon reductants, one measure relating to the design of steel (Measure 3), and one measure relating to the design of steel products (Measure 7).

At the manufacture stage of the lifecycle there are three measures, one relating to the method used to manufacture steel (Measure 4), and two relating to process efficiencies in manufacturing (Measures 5 and 6).

Finally, at the end of the lifecycle Measure 8 deals with the different life extension (repair) and end-of-life pathways (reuse, manufacturing and recycling) of the steel products.

4.3 Drivers & Barriers

Throughout the research, a range of drivers and barriers were identified for each of the measures. The most important ones are identified in Table 9.

Table 9: Top drivers and barriers for steel measures

#	Measure name	Top drivers	Top barriers
1	Substitution of fossil-carbon reductant with waste-based alternatives	Operational flexibility through wider choice of feedstocks. Lack of biomass feedstock availability.	Emissions limits for contaminants such as dioxin and furan.
2	Substitution of fossil-carbon reductants through use of hydrogen to produce direct reduced iron in EAFs	Increasing availability of renewable energy sources for steel making.	UK has sufficient scrap supply for EAFs, without need of DRI. Limited availability of green hydrogen and demand increasing from other sectors.
3	Transition from ore-based to scrap-based steel production	Transition to EAF.	Lack of support of and investment into the UK scrap steel market.

#	Measure name	Top drivers	Top barriers
			Technical limits meaning traditional blast furnaces can only use 25% scrap material. Certain contaminants are costly to remove and volumes may not justify investment. Downcycling of high-grade scrap needs to be avoided. Increased costs of sorting and managing scrap.
4	Transition from basic oxygen furnace to electric arc furnace steelmaking	Increasing pressure to reduce emissions.	High and volatile energy prices. Significant upfront costs and time to construct new EAF infrastructure.
5	Recovery and utilisation of process off-gases	Emissions reduction polices and drivers.	Upfront financial costs of implementing technologies. Already widely used in UK BF-BOF steelmaking. Not relevant to EAF steel production.
6	Recovery and use of steelmaking by-product materials	Wide range of options for reuse of by-products. Emission reduction policies and drivers.	Risk of hazardous materials in by-products.
7	Light-weighting and use of higher grades of steel in consumer products	New design technologies like artificial intelligence could increase light-weighting, although there is a physical limit to this strategy. Scope 3 emissions reporting will enable a decrease in embodied carbon.	Lack of financial incentives for changing current manufacturing methods.
8	Increased reuse, repair, remanufacture and recycling of steel-based products	Planning regulations in the construction sector.	The standards for product design may constitute a barrier in the enabling of the regenerative approaches of repair and remanufacture.

As has been seen in the other sectors, a key driver of resource efficiency improvements in the steel sector is the drive to decarbonise/national emissions reduction targets. This is a listed as a key driver for almost all of the resource efficiency measures in the sector.

By contrast, the barriers to improvements tend to be more measure specific. For example, the key barriers to Measures 1 – 2 (which all relate to the substitution of fossil carbon reductants) are pollution/contaminants (Measure 1) and the availability of scrap and use of EAFs (Measure 2).

The one key barrier that appears across multiple measures is use of EAFs in steelmaking, and the availability of scrap steel (Measures 2 – 5). This is because EAF's can produce steel with a much high recycled content than BF-BOF steel, and because the technology required for some measures can only be used for EAF production.

4.4 Levels of efficiency

Table 10: Levels of efficiency and evidence RAG rating (*in italics*) for the steel measures

#	Measure name	Indicator	Current	Maximum in 2035	Business-as-usual in 2035
1	Substitution of fossil-carbon reductant with waste-based alternatives	% of reductant (in weight) replaced by plastic or rubber waste alternatives	0% *Amber*	0 – 5% *Red*	0 – 1% *Amber*
2	Substitution of fossil-carbon reductants through use of hydrogen to produce direct reduced iron in EAFs	% of UK crude steel produced using hydrogen-DRI-EAF	0% *Amber*	15 – 30% *Red*	0 – 15% *Red*
3	Transition from ore-based to scrap-based steel production	% of scrap per tonne of crude steel for BF-BOF and EAF in the UK steel production	BF-BOF: 20% EAF: 100% *Green*	BF-BOF: 25% EAF: 100% *Amber-Green*	BF-BOF: 20% EAF: 100% *Amber-Green*
4	Transition from basic oxygen furnace to electric arc furnace steelmaking	% of UK crude steel produced using EAF	18% *Green*	100% *Amber*	N/A
5	Recovery and utilisation of process off-gases	% reduction in carbon inputs	N/A	N/A	N/A
6	Recovery and use of steelmaking by-product materials	% of steelmaking by-products recovered and used	95 – 100% *Red-Amber*	95 – 100% *Amber*	95 – 100% *Amber*
7	Light-weighting and use of higher grades of steel in consumer products	% of reduction in weight of consumer product	0% *N/A*	10 – 40% *Red - Amber*	0 – 30% *Red*
8	Increased reuse of steel-based products	% of reused steel in a product	0 – 14% *Amber*	30 – 44% *Red*	0 – 30% *Red*

#	Measure name	Indicator	Current	Maximum in 2035	Business-as-usual in 2035
	Increased repair of steel-based products	% of repaired steel in a product	15 – 29% *Red*	15 – 29% *Red*	15 – 29% *Red*
	Increased remanufacture of steel-based products	% of remanufactured steel in a product	0 – 14% *Red*	15 – 29% *Red*	0 – 20% *Red*
	Increased recycling of steel-based products	% of recycled steel in a product	80 – 90% *Green*	>90% *Amber-Green*	>90% *Amber-Green*

General insights

In the steel sector the majority of measures have a BAU level of efficiency that is higher than the current level of efficiency, but lower than the maximum level of efficiency suggesting that improvements in resource efficiency are expected in the current environment, but that these improvements will not deliver all the available resource efficiency potential. This is similar to what has been seen in other sectors.

However, in contrast to other sectors, there are also some measures identified in the steel sector where the current, BAU and maximum levels of efficiency are the same, suggesting the industry has already maximised the potential of these measures and there are no further improvements to be made (Measures 6 and Measure 8 recycling). These relate to process efficiencies where this is a clear financial incentive for the steel producer to make improvements, and where the technology to make these improvements is already well-established.

The other key difference between the steel sector and the other sectors in this study is clear interdependencies between measures, with the potential for multiple measures dependant on whether steel production is via BF-BOF or EAF's (Measure 4). Whether the steel industry transitions to greater EAF production is a live question in the sector and is beyond the scope of this project. Because of this, where levels of efficiency differ between BF-BOF and EAF steel production both scenarios have been presented.

Measure specific insights

Measures 1 and 2 have not been extensively explored or implemented in the UK steel production. Measure 2 is seen as a particularly significant option for the decarbonisation of the steel sector, but its deployment requires considerable financial and policy incentives.

The next measure (Measure 3) has the highest overall potential for the sector. However, whether this potential is achieved is highly dependent on Measure 4. This is because the % of scrap steel per tonne of crude steel that can be produced is much higher in EAF steel-making than in BF-BOF steel-making. Whether the steel industry transitions to greater EAF production is a live question in the sector and is beyond the scope of this project.

Measure 5 had limited evidence and this report was unable to make conclusions regarding the levels of efficiency for this measure. More research is needed to understand the potential for resource efficiency from this measure.

Measure 6 which relates to process efficiency in the manufacturing process, and has the same level of efficiency for the current, BAU and maximum levels. This suggests that this measure is already being implemented at a maximum levels of resource efficiency and there is no untapped potential.

Finally, Measures 7 and 8 deal with steel products, and can be highly variable according to the different end products. Thus, the levels of efficiency presented here (which cover the sector as a whole) are expressed in wide ranges and tend to have low evidence RAG ratings. Information on these measures for specific steel-containing products e.g., vehicles, construction and electricals are included in the corresponding sector specific reports. At the whole sector level, it is worth noting that there is both more evidence available and higher current and expected levels of efficiency for end-of-life measures relating to steel recycling, compared to other circularity strategies, despite recycling being lower down the waste

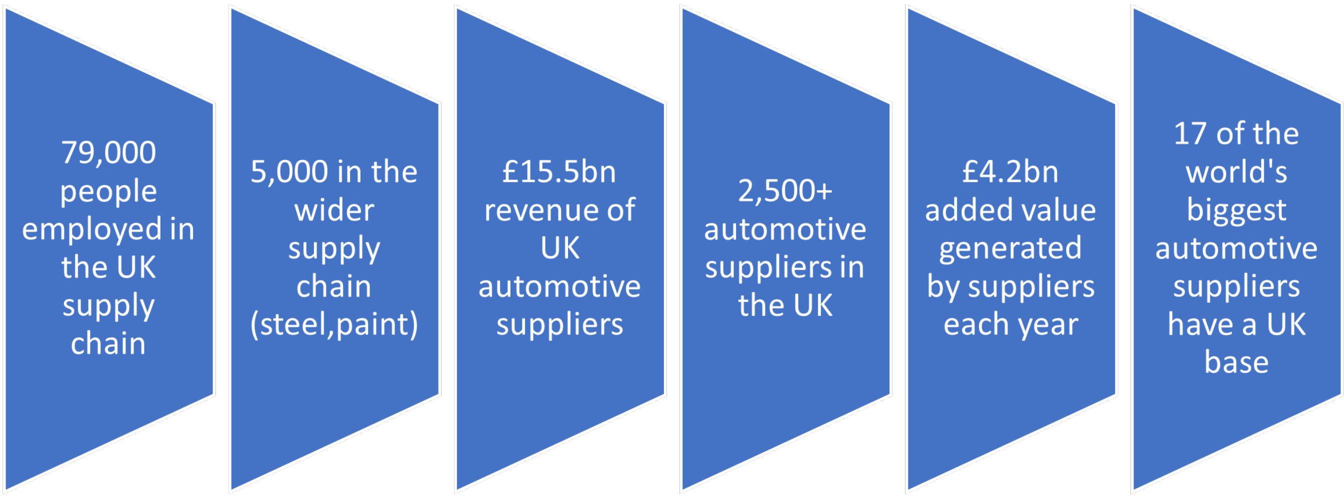
5. Vehicles

This section summarises the key findings regarding the list of resource efficiency measures, the top drivers and barriers for each measure and the levels of efficiency (and associated evidence RAG ratings) for the vehicles sector. The complete findings are presented in the Unlocking Resource Efficiency: Phase 1 Vehicles Report.

5.1 Sector introduction

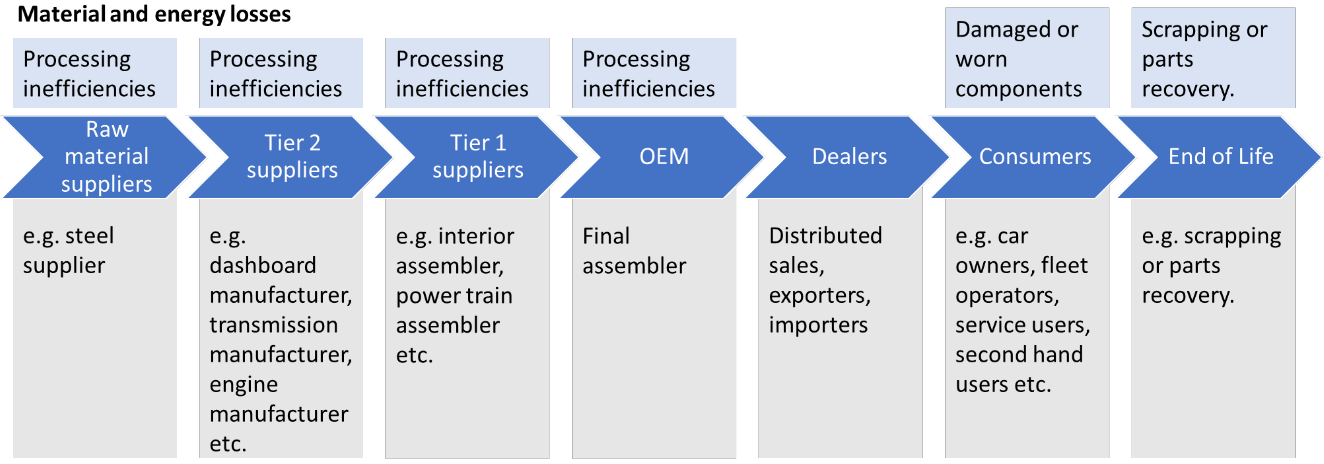
The UK vehicles sector is a key sector within the UK economy, with the automotive sector alone generating an estimated £67 billion in turnover in 2021.[18] According to ONS data, 11% by value of all UK manufactured goods were motor vehicles, trailers and semi-trailers in 2021.[19] Additionally, automotive and motor vehicles were the UK's most exported commodities by value at £32 billion in 2022.[20] Furthermore, the wider supply chain is a major employer and economic contributor to the UK economy:

Figure 2: Automotive supply chain in the UK, Society of Motor Manufacturers and Traders (2023)[21]



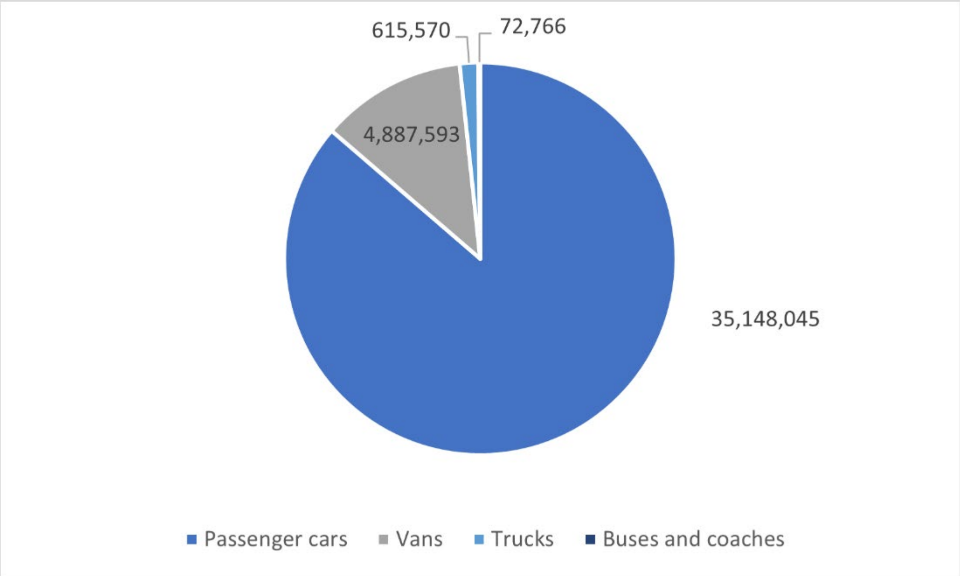
[18] The Society of Motor Manufacturers and Traders (2023) SMMT Motor Industry Facts 2023 link
[19] Office for National Statistics (2022) UK manufacturers' sales by product link
[20] The Society of Motor Manufacturers and Traders (2023) SMMT Motor Industry Facts 2023 link
[21] The Society of Motor Manufacturers and Traders (2023) SMMT Motor Industry Facts 2023 link

Figure 3: Material and energy losses in the supply chain



The automotive sector is dominated by passenger cars and light commercial vehicles such as vans. These two categories together made up 98% of all automotive vehicles on the road in the UK in 2022.

Figure 4: Vehicles on the road in 2022[22]



Within passenger cars, a clear trend is visible towards larger and heavier vehicles. According to Green NCAP, between 2012 and 2022 the average weight of automotive vehicles sold in Europe increased by 9% or around 100 kg.[23] This is reflected in UK sales figures too, in 2013 SUVs, or dual-purpose vehicles, made up 11% of new vehicle registrations, whereas in 2022 this figure stood at 27%.[24]

The UK vehicles sector also significantly contributes to the UK's resource consumption; in 2019 the automotive industry and the aerospace industry were the largest and second largest

---

[22] The Society of Motor Manufacturers and Traders (2023) SMMT Motor Industry Facts 2023 link
[23] Green NCAP (2023) Green NCAP: the size of your car does matter link
[24] The Society of Motor Manufacturers and Traders (2023) SMMT Motor Industry Facts 2023 link

users of basic iron and steel, by value, in the UK.[25] Additionally, the automotive industry was the second largest user of rubber and plastic products as well as paints, varnishes and similar coatings, only behind the construction industry in both.[26]

Resource efficiency in the vehicles sector focuses on optimising the use of materials throughout the entire lifecycle of the vehicles from raw material extraction to end of life (EoL). Examples of key resource efficiency measures in the sector include:

- efficient use of materials in production through light-weighting and improved waste-management;
- using materials with a lower whole-life carbon;
- using vehicles more efficiently, for example through car-sharing, ride-hailing etc.
- extending vehicle lifetime through enhancing their durability and designing for repair at EoL.

Vehicles production requires significant quantities of raw materials, particularly steel which are energy and carbon intensive to produce. Resource efficiency measures therefore help reduce the overall environmental impact of the sector by optimising material usage, reducing emissions, minimising waste generation and conserving energy.

Using resources more efficiently can also result in cost savings through a reduction in raw material use, and a switch to potentially cheaper alternative materials. The vehicles sector is resource-intensive, and any wastage or inefficiency in material usage can result in significant financial losses. By adopting resource-efficient practices, the sector can reduce costs and enhance its competitiveness.

Decarbonisation in the vehicles sector

Currently the vast majority of UK vehicles use petrol and diesel. However, as part of the drive to decarbonise the vehicles sector, in line with the UK commitment to reach Net Zero greenhouse gas emissions by 2050[27] the UK Government has committed to ensuring that 80% of new cars and 70% of new vans sold in Great Britain will be zero emission by 2030, increasing to 100% by 2035.[28]As a result, the industry is undergoing a substantial transition, with battery power vehicles making up a growing proportion of the market. According to vehicle licensing statistics from January to March 2023, battery EVs accounted for 17% of new car registrations in the UK, while plug-in hybrid EVs made up 12%, and this is expected to continue to grow at a rapid rate[29].

The trend towards electric vehicles is driving substantial changes in the vehicles sector which impact the potential and incentives for different resource efficiency measures. These are discussed in detail in this report.

[25] Office for National Statistics (2023) UK input-output analytical tables, product by product. Table “Use BP PxI” link
[26] Office for National Statistics (2023) UK input-output analytical tables, product by product. Table “Use BP PxI” link
[27] UK Government (2019) UK becomes first major economy to pass net zero emissions law link
[28] UK Government (2023) Government sets out path to zero emission vehicles by 2035. Available at link
[29] Department for Transport (2023) Vehicle licensing statistics: January to March 2023 link

Additionally, carsharing and ridesharing services have risen in prominence and now make up a significant part of the vehicles on the UK's roads, with the potential to increase car occupancy levels and in turn reducing overall miles travelled.

Sector Scope

The scope of this report covers resource efficiency measures as they relate to road vehicles. While predominantly focussing on passenger vehicles it includes light goods vehicles, HGVs, buses and coaches. The focus of interest is on aspects of design and manufacturer, considering lightweighting and selection of materials as well as management of materials in production. Some aspects of life extension and re-purposing are also considered.

The following topics are out of scope:

- Vehicles: Non-road mobile machinery, agricultural vehicles, motorcycles/mopeds/scooters, maritime, air and rail transport vehicles;
- Modal shift: No consideration of modal shift is included in the current analysis. Passenger behaviours in terms of use of vehicles is assumed to be as current modal mix;
- Alternative fuels and energy efficiency: Current energy use and default fuel use in vehicles are not considered as resource efficiency measures here. Environmental initiatives involving alternative fuels or deep decarbonisation, such as Carbon Capture Utilisation and Storage (CCUS), are excluded.

5.2 List of resource efficiency measures

A list of the identified measures can be found in Table 11. The measures span the full supply chain with the design phase having the most identified measures.

Table 11: List of measures for the vehicles sector

#	Lifecycle stage	Strategy	Measure name	Measure indicator
1	Design	Light-weighting	Light-weighting through material substitution	The % of reduction of average passenger vehicle weight relative to 2023 levels.
2	Design	Light-weighting	Light-weighting through reducing vehicle size	The % of reduction of average passenger vehicle weight relative to 2023 levels.
3	Design	Use of secondary raw materials	Use of recycled content in vehicle products	The % weight of recycled content in vehicle products that displace virgin material.
4	Design	Material substitution	Use of biobased materials in vehicle products	The % vehicle weight that is biobased content and displaces virgin or recycled plastics.

#	Lifecycle stage	Strategy	Measure name	Measure indicator
5	Manufacture and Assembly	Production efficiencies	Recycling of wastes generated in production processes	The recycling rate of waste from production processes.
6	Sales and Use	Collaborative consumption	Car-sharing and increased vehicle occupancy	The % of vehicles within car clubs, car rental organisations, private car hires and car rideshares as a proportion of vehicles on the road.
7	Sales and Use	Life extension	Vehicle life extension	The % of vehicles whose lifetime is extended through electrification at end of life. The % of vehicles that are currently scrapped whose lifespan could be extended through repair.
8	End-of-life measures	Remanufacturing	Remanufacturing, reuse and reconditioning of parts	The % vehicle weight reused, remanufactured or reconditioned.
9	Manufacture and Assembly	Production efficiencies	Reducing waste in manufacturing	The production waste avoided as a % of vehicle weight.

5.3 Drivers & Barriers

Throughout the research, a range of drivers and barriers were identified for each of the measures. The most important ones are identified in Table 12.

Table 12: Top drivers and barriers for vehicles measures

#	Measure name	Top drivers	Top barriers
1	Light-weighting through material substitution	Improved journey range for EVs. Consumer demand for “greener” vehicles.	Uncertainty on wider environmental impacts. Increased complexity of end-of-life treatment for certain materials. Increased costs to OEMs.
2	Light-weighting through reducing vehicle size	Improved fuel range and efficiency.	Lack of flexibility / usefulness of smaller vehicles. Consumer preference trending towards larger vehicles. Technical challenges on battery requirements. Smaller vehicles could mean more vehicles on the roads. Smaller passenger vehicles can be less profitable for manufacturers.

#	Measure name	Top drivers	Top barriers
3	Use of recycled content in vehicle products	Reduce the reliance on virgin materials and associated supply chain pressures.	Supply chain issues result in inconsistent feedstock and competition. Downcycling of ELV materials limits closed-loop recycling.
4	Use of biobased materials in vehicle products	Improved efficiencies from replacing heavier parts with biobased plastic alternatives.	Limited understanding of environmental benefits (or otherwise), including carbon impacts and recyclability can hinder or deter greater uptake.
5	Recycling of wastes generated in production processes	OEM sustainability commitments. Reduced reliance on virgin materials and associated supply chain pressures. Political and consumer demand for zero waste products and organisations.	Lack of clarity and robustness of waste data. Poor collaboration between OEMs, suppliers and recyclers prevents closed-loop recovery.
6	Car-sharing and increased vehicle occupancy	Incentivisation for the public to use car sharing clubs. Changing consumer attitudes towards non-ownership models. Environmental and health benefits of reduced air pollution.	Lack of convenience, flexibility and reliability compared to ownership models. Poor journey planning integration. Lack of coherent national policy and messaging.
7	Vehicle life extension	Lifecycle carbon savings from reduced energy in production and few in-use emissions. Incentives to repair through ownership models. Existing public acceptance for repair processes.	Underdeveloped legislative / safety requirements around electrification deters uptake by consumers and manufacturers. Technical requirements hinder uptake of electrification.
8	Remanufacture-ring, reuse and reconditioning of parts	Supply chain benefits. Interest from insurers to use remanufactured, refurbished and reused parts.	Lack of clear guidance and standards to ensure safety. Technical limitations in disassembly for reuse Compatibility with insurance / warranty.
9	Reducing waste in manufacturing	Reduced supply costs and reduced waste management costs. OEM sustainability commitments facilitate waste reductions.	Limitations in consumer and purchaser appetite for open loop recycling Lack of knowledge and human resources in the supply chain around closed loop recycling.

As in other sectors, as key cross cutting barrier in the vehicles sector is consumer demand for sustainable/lower carbon products and brand sustainability/decarbonisation commitments. This is a top driver for over half of the resource efficiency measures identified (Measures 1, 2, 5, 6, 7 and 9).

However, in the vehicles sector specifically consumer demand/preferences can also act as a barrier to some resource efficiency measures with consumer demand for larger vehicles highlighted as a key barrier to reducing vehicle size (Measure 2).

Another key cross-cutting barrier is technical/technological limitations which are generally linked to the drive to electrify vehicles. For example, for Measure 2 EV batteries are heavier than traditional internal combustion engines so vehicle electrification tends to increase vehicle weight (though this can be compensated for by reductions in weight elsewhere), and for Measure 7 the need to electrify vehicles increases the technical challenge of increasing the lifespan of existing internal combustion engines.

Finally, lack of data is also a key barrier in several cases - Measures 1 and 4 suffer from the lack of understanding of wider environmental impacts on the material substitutions, and Measure 5 struggles with lack of clarity and robustness of waste data.

5.4 Levels of efficiency

Table 13 shows the levels of efficiency for each vehicles resource efficiency measure, with the associated evidence RAG rating.

Table 13: Levels of efficiency and evidence RAG rating (*in italics*) for the vehicles measures

#	Measure name	Indicator	Current	Maximum in 2035	Business-as-usual in 2035
1	Light-weighting through material substitution	The % of reduction of average passenger vehicle weight relative to 2023 levels.	0% *N/A*	20 – 35% (by 2050) *Amber-Green*	10 – 20% *Red-Amber*
2	Light-weighting through reducing vehicle size	The % of reduction of average passenger vehicle weight relative to 2023 levels.	0% *N/A*	20 – 40% *Amber-Green*	-10-0% *Red*
3	Use of recycled content in vehicle products	The % weight of recycled content in vehicle products that displace virgin material.	10 – 16% *Red*	80 – 100% *Red*	30 – 40% *Red*
4	Use of biobased materials in vehicle products	The % vehicle weight that is biobased content and displaces virgin or recycled plastics.	5% *Red-Amber*	10 – 40% *Red-Amber*	N/A
5	Recycling of wastes generated in production processes	The recycling rate of waste from production processes.	94% *Green*	100% *Green*	98% *Amber*
6	Car-sharing and increased	The % of vehicles within car clubs, car rental organisations,	0.01% *Green*	30 – 40% *Red-Amber*	10 – 20% *Red-Amber*

#	Measure name	Indicator	Current	Maximum in 2035	Business-as-usual in 2035
	vehicle occupancy	private car hires and car rideshares as a proportion of vehicles on the road.			
7	Vehicle life extension	The % of vehicles whose lifetime is extended through electrification at end of life. The % of vehicles that are currently scrapped whose lifespan could be extended through repair.	Electrification: 0 –5% Repair: 0 – 20% *Red-Amber*	Electrification: 0 – 20% Repair: 20 – 40% *Red-Amber*	Electrification: 0 – 10% Repair: N/A *Red*
8	Remanufacturing, reuse and reconditioning of parts	The % vehicle weight reused, remanufactured or reconditioned.	0-10% *Red*	40% *Amber-Green*	8 – 10% *Red*
9	Reducing waste in manufacturing	The production waste avoided as a % of vehicle weight.	60 – 80% *Red*	80 – 100% *Red-Amber*	80% *Red*

General insights

As with the other sectors covered in this report, the key trend seen in the levels of efficiency from the vehicles sector, is that the BAU level of efficiency lies between the current level of efficiency and the maximum level of efficiency, suggesting some improvement in the current environment, but that changes would be needed for the potential to be maximised.

A key factor which influences the BAU and maximum levels of efficiency (and the difference between them), in this sector but not in other sectors, is the shift towards electric vehicles. Electric vehicles have different properties than ICE vehicles (e.g., batteries are heavier than ICE, increased importance of journey range, different economics, currently smaller resale market), which impacts the resource efficiency potential from different measures. In some cases this can act as a driver for improved resource efficiency (e.g., Measure 1 where increase battery weight and the importance of journey range is expected to driver light weighting improvements in the rest of the vehicle), but sometimes this can be a barrier (e.g., for lifetime extension of ICE vehicles). More detail on how different measures are impacted can be found in the discussion below, and in the sector specific report.

Measure specific insights

The two light-weighting measures (Measure 1 and 2) show high levels of potential with high evidence RAG rating for the maximum levels of efficiency. Both measures are likely to improve on current levels of efficiency due to the increasing drive to lightweight electric vehicles and rapidly advancing improvements in materials and manufacturing technology. However, stakeholders cautioned that electric vehicles are inherently heavier than internal combustion engine vehicles so this may skew current estimates. Stakeholders also noted the increasing consumer preference for larger vehicles which poses a barrier towards uptake of this measure. Nevertheless, both measures could achieve a maximum improvement of 20-35% (or 20-40%) on current levels of efficiency. It is worth noting that the current level of efficiency has been set to 0% as a baseline and should not be interpreted as starting from scratch on this measure. More details can be found in the accompanying ‘Vehicles Resource Efficiency Measures’ report, where information is provided on the considerable efforts already made by the sector in vehicle light-weighting over the past years.

Measure 3 and Measure 4 show a reasonably high level of potential under a BAU scenario largely driven by OEM sustainability commitments as a result of consumer demand for sustainability and embodied carbon savings. Recycled content in vehicles could approach 100% theoretically but is unlikely without the development of supply chains whereas the opportunity for the use of biobased content is limited to certain (plastic) components (around 40%). Substitution with these materials for safety-critical components require certification which prevents widespread uptake.

The two measures on the manufacture and assembly phase (Measure 5 and 9) are the most advanced in terms of resource efficiency; this can be seen in the high levels of efficiency for the current values, and the expectation that the BAU in 2035 will be relatively close to the maximum levels. OEMs already offer high levels of material efficiency in their processes due to the economic incentives of maximising stock and reducing waste disposal costs therefore improvements on current levels of efficiency are likely to be marginal.

Measure 6, car-sharing and increased vehicle occupancy, shows potential maximum level of efficiency of 30-40%, though this will require significant behavioural change by consumers to servitised business models. (see Section 1.3.3 of the accompanying ‘Vehicles Resource Efficiency Measures’ report for further details). The BAU (10%) shows a potential for a large improvement from the low current level of efficiency (<1%) and that this is an effective measure to reduce consumption of new vehicles given that consumers, particularly younger users, are adopting this measure. Stakeholders stressed that improved user engagement and accessibility is critical to successful uptake of this measure.

Measure 7 is split into two levels; Electrification of internal combustion engine vehicles (at End of Life or during use); and repair of vehicles at End of Life. Stakeholders largely agreed that electrification of passenger and freight internal combustion engine vehicles is impractical and is likely to be for niche purposes only. Conversely, stakeholders noted that vehicle repairs in the UK are already widely implemented so there is limited opportunity to improve further on current levels of efficiency. Nevertheless, there is room to further improve on repair rates and maximising component lifespans.

Measure 8 is quite unique since the evidence RAG rating is much higher for the maximum level of efficiency compared to the current level, as opposed to the rest of the measures. Stakeholders noted that the insurance industry has a large impact on the use of secondary components. Increasing interest in remanufactured parts by insurers is likely to drive uptake of this measure significantly. Stakeholders noted that it is vital that consumers have confidence in using secondary components that meet a standard and do not impact their insurance premiums.

Overall, the evidence RAG ratings for the vehicles sector are quite widespread, with some measures showing high evidence RAG rating (Measure 5 and 6) and other measures showing very little quantitative data and/or stakeholder inputs (for example, Measure 3, 4 and 9).

6. Conclusion

6.1 Strategies across resource efficiency measures

All the identified measures across the five sectors have been categorised into one of eight resource efficiency strategies. More information is provided in Annex A.

Figure 5: Mapping of sector measures under the lifecycle phases and resource efficiency strategies

	Design			Manufacturing & assembly	Sale & Use		End of life	
	Light-weighting	Material substitution	Recycled content	Production efficiencies	Collaborative consumption	Life extension	Remanufacture / reuse	Recycling
Cement & concrete	<<<<< Measure 1 >>>> Measure 4		Measure 2 Measure 3	Measure 5				Measure 6
Construction	Measure 3	Measure 2	Measure 1	Measure 4		Measure 5		Measure 6
Steel	Measure 7	Measure 1 Measure 2	Measure 3	Measure 5 Measure 6		<<<<<<<<<< Measure 8 >>>>>>>>>		
Vehicles	Measure 1 Measure 2	Measure 4	Measure 3	Measure 5 Measure 9	Measure 6	Measure 7	Measure 8	

Comparing the different measures in each strategy across sectors reveals the following insights:

- **Light-weighting** can take place in all sectors. These four sectors (cement and concrete, construction, steel and vehicles) have reported instances of over-design or over-specification.
    - Vehicles has two light-weighting measures as these refer to the two different modes of light-weighting: through material substitution (Measure 1) and through reduction of vehicle size (Measure 2).
    - Cement and concrete also have two measures, referring to different parts of the value chain: Measure 1 discusses to the reduction of Portland cement (CEM I) in concrete and Measure 4 describes reduced use of concrete in buildings.
- **Material Substitution**[30] is present across all sectors. The four sectors have opportunities for replacing material use with lower carbon materials, although the issue of the boundaries of the carbon lifecycle has been brought up by the stakeholders.
    - The steel sector has two measures discussing the substitution of fossil-carbon reductants with three different products: Waste-based alternatives in Measure 1 and hydrogen direct reduced iron in Measure 2.

[30] As discussed in the introduction, material substitution does not meet the definition of resource efficiency but is considered in scope of this study.

  - Measure 1 of cement and concrete, reduction of Portland cement (CEM I) in concrete, can be considered both a light-weighting and a material substitution measure as there are several available substitutes such as pulverised fly ash, ground granulated blast furnace slag, limestone, etc.

- The **use of recycled content** (or secondary raw materials) is common across the five sectors, and in the case of cement and concrete, there are two measures under this strategy.

- **Production efficiencies** are present in all sectors, and in three cases with two measures. This reflects the more traditional approaches to resource efficiency, more focused around the manufacturing processes and less complex value chain interactions. It should be noted that these measures also tend to be those where most progress has already been made in the sector, with the potential for further improvement being lower.

- **Collaborative consumption** discusses alternative business models to the traditional approach of one buyer – one user. This strategy is only present for vehicles measures, which are final products (as opposed to cement and concrete and steel) and portable assets that can be shared (as opposed to construction).

- **Lifetime extension** is present in all sectors except for cement and concrete. This is due to the nature of the sector – the lifetime of concrete is generally much longer than the lifespan of the building, so the ultimate duration of cement and concrete products will depend on the duration of the building. Each sector has identified different ways to extend product lifetime, with electrification being unique to vehicles and refurbishment more applicable to construction.

- Finally, the **end-of-life** stage of the lifecycle has different available strategies for each sector:

  - Cement and concrete is focused on the recycling of concrete into cement and concrete;

  - Construction discusses both reuse and recycling as a single measure – at the level of a building (e.g., Measure 5) and level of building materials/components (e.g., measure 1 and 6), with two different indicators;

  - Steel being a raw material, the end of life will be highly dependent on the nature of the final product[31], so there are many dependencies with the vehicles and construction sector, but also electricals (part of phase 2 of the research);

  - Vehicles discusses the end of life under a single measure with three strategies: reuse, reconditioning and recycling; and

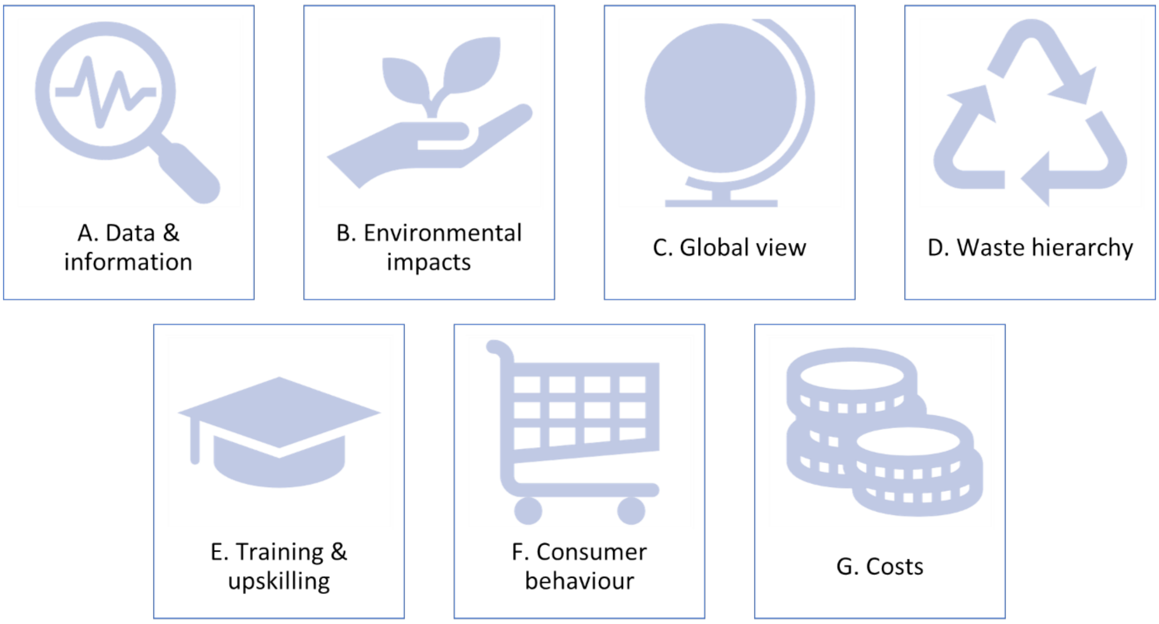
  - Generally, levels of recycling tend to be higher than levels of reuse, and improvements in recycling in a BAU scenario are more likely than improvements in reuse, despite reuse being favoured due to greater environmental benefits.

[31] For example, steel beams in construction have high reuse potential while repair is a good solution for medical instruments made of stainless steel.

6.2 Themes across resource efficiency measures

There are several topics or themes that have consistently emerged in the literature review and stakeholder engagement for the five sectors.

Figure 6: Key themes across the resource efficiency measures



The seven themes are described below as well as the identified interdependencies between the themes.

A. Data & information

Stakeholders across the five sectors mentioned the importance of reliable data about the products and the manufacturing processes so to ensure that materials and products can be recycled or reused.

Measures under the strategy ‘use of secondary materials’ usually mentioned data as a barrier, as manufacturers need data about the available material and its previous use history, so that it can be safely reintroduced into a new product. This was mentioned in construction Measure 1 for the reused building components and steel Measure 3 for the transition from ore-based to scrap-based steel production. Lack of data can also hinder recyclability, as recyclers are sometimes uncertain about the presence of contaminants or substances that hinder recycling.

Techniques to improve data such as labelling, digital product passports or even building passports were believed to be an enabler or driver when present, or a barrier when missing. These can be used to convey important information. Material passports are identified as a key driver for steel Measure 8, related to repair, reuse and remanufacturing of steel products.

In some cases, the ability to gather data through a resource efficiency measure was perceived to be a driver. In some cases, the issue was not with the lack of data, but the exchange of data across the different actors of the value chain.

B. Environmental impacts

Stakeholders agreed that resource efficiency is not considered in isolation from environmental impacts and that there are highly complex dependencies between different environmental impacts:

- In some cases, resource efficiency measures can lead to carbon savings. This is identified as a driver in several measures, vehicles Measure 3 (use of recycled content), vehicles Measure 5 (recycling of wastes generated in production processes).
- In other cases, resource efficiency measures can result in a trade-off with decarbonisation measures, such as the increased carbon footprint of logistic operations in EoL measures. This was mentioned as a barrier for construction Measure 7.
- Finally, there are cases where the lack of data on environmental impacts is a barrier itself and this is present in some of the measures with material substitution as the main strategy:
    - Lack of data is one of the top barriers of vehicles Measure 1 (light-weighting through material substitution). In academia, there is a lack of data/consensus that light-weighting reduces carbon emissions. Although light-weighting can reduce in-use emissions, vehicle production impacts can remain high (or be higher) for certain materials and components compared to traditional materials such as steel.
    - Additionally, in vehicles Measure 4 (use of biobased materials in vehicle products) the literature review highlighted a lack of understanding surrounding the environmental benefits of biobased materials as the most prominent barrier to this measure. This was corroborated by the stakeholders who emphasised that the impacts of biobased materials are not universally positive, as is sometimes promoted.
- Several concerns were raised about the environmental impacts of material substitution, especially where those were regenerative materials (bioplastics in vehicles Measure 4, timber in construction Measure 2)
- Beyond the carbon impacts of the resource efficiency measures, stakeholders highlighted other environmental impacts such as changes in land use, ecosystem and biodiversity.
- Existing environmental commitments, for example brand commitments, were identified as the top driver for vehicles Measures 3 and 9.

C. Global view

Due to the globalised value chains, many sectors have extensive trade (import and export) through various stages of the lifecycle. This has an impact on the extent to which different resource efficiency measures can be impacted by UK action.

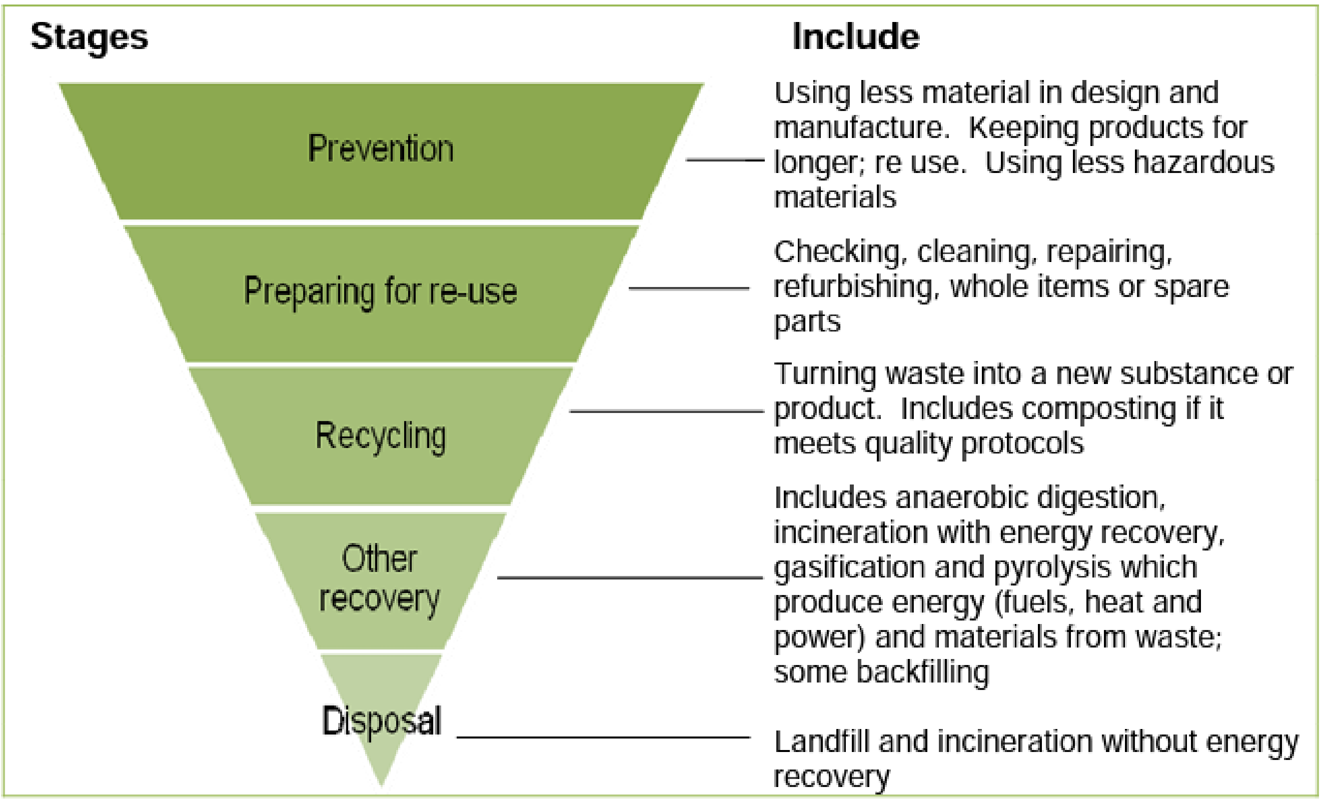
- In many cases the UK imports manufactured products, which means resource efficiency measures on the manufacturing side take place overseas and are difficult to monitor.

- The UK also exports manufactured products and this affects the sales and use and EoL measures. If a product is sold overseas, any downstream resource efficiency measures are not likely to take place in the UK and/or be impacted by UK action.
    - The vehicles sector also has a significant share of export; Measure 6 (car-sharing and increased vehicle occupancy), Measure 7 (life extension through electrification and repair), and Measure 8 (remanufacturing, reuse and reconditioning of parts) would then happen in other countries.
- The UK exports EoL materials and this has been flagged as a barrier for resource efficiency as it prevents the re-introduction of EoL materials / products into the UK value chains.
- Finally, the UK can import EoL materials, which can be a driver of some resource efficiency measures.
    - The steel sector has identified that scrap is a global commodity, with the UK being both an importer and exporter of scrap.

D. Waste hierarchy

Resource efficiency measures occur throughout the supply chain. The waste hierarchy gives a framework for how these measures should be prioritised, which was broadly accepted by stakeholders.

Figure 7: Diagram of the waste hierarchy[32]



[32] Defra (2011): Guidance on applying the Waste Hierarchy, available at https://www.gov.uk/government/publications/guidance-on-applying-the-waste-hierarchy

The literature sources and the stakeholders made the following comments about the waste hierarchy and the importance of following the order of priority.

- In cement and concrete, Measure 1 received the highest level of engagement from stakeholders in the workshops and was covered the most extensively in the literature. This is consistent with the waste hierarchy framework in that Measure 1 is aligned with the highest tier of the hierarchy (i.e., preventing the unnecessary use of Portland cement (CEM I in concrete).
- In construction, several stakeholders insisted on the need to prioritise reuse over recycling under Measure 7, with the distinction that building components are reused while building materials are recycled.
- In steel, there is such a high demand for scrap, that market economics may favour recycling instead of repair or reuse (Measure 8), which goes against the waste hierarchy.
- Vehicles Measure 8 (Remanufacturing, reuse and reconditioning of parts) describes the three techniques, each with their own challenges.

Stakeholders have also highlighted the trade-offs between the different parts of the waste hierarchy:

- Light-weighting would fall under “waste prevention”, which should be priority. However, light-weighting can lead to reduced lifetime (thus increased waste) and/or reduced recyclability and/or may conflict with the incorporation of recycled content. These have been identified as barriers for vehicles Measure 1 (light-weighting through material substitution).
- Stakeholders also mentioned that not all recycling is comparable, and in some cases, products are ‘downcycled’, i.e., recycled into lower value applications. This was mentioned as a barrier for vehicles Measure 1 (light-weighting through material substitution), and construction Measure 6 (recycling and reuse).

E. Training & upskilling

Many of the identified drivers and barriers revolved around the skillset of the workforce. In some cases, the lack of skillset was identified as a barrier to achieving the maximum levels of efficiency for the resource efficiency measures. In other cases, the resource efficiency measures would result in job creation, which is both perceived as a barrier (due to increased cost) but also as a driver in terms of driving sector growth and social impacts.

- In the construction sector Measure 4 (reduction of process wastage), lack of relevant training is a barrier.
- For the steel sector, a transition from BF-BOF to EAF (Measure 3) would require significant reskilling of the workforce, as these are two very different manufacturing techniques. Alternatively, an uptake of Measure 8 in steel (product requirements for circular use) is believed to lead to job creation.
- For the vehicles sector, Measure 8 deals with remanufacturing, reuse and reconditioning, and lack of training is mentioned as a barrier.

This theme was not mentioned in the cement and concrete sector.

F. Consumer behaviour

Consumers drive demand for products and consumer preferences can have a large impact in the uptake of some resource efficiency measures. Product manufacturers monitor consumer trends to adapt to changing preferences.

In some cases, the consumer preferences can go in the opposite direction of the resource efficiency measures. For example, consumer preference for larger vehicles (such as SUVs) was identified as a barrier in the vehicles sector for Measure 2 (light-weighting through reducing vehicle size). Also, vehicles Measure 8 (remanufacturing, reuse and reconditioning of parts) identified consumer behaviour as a barrier, since reconditioned goods can be perceived as having lower quality and reliability.

In other cases, increased consumer awareness of the benefits (generally the environmental benefits) of resource efficiency is identified as a driver. This is evident in the vehicles sector Measure 1, light weighting through material substitution.

Consumer behaviour is especially relevant for the measures under the strategy of collaborative consumption. It appears as both a driver (growing demand) and a barrier (need for behaviour / mindset change) for a range of sectors. This is seen in vehicles Measure 6, car-sharing and increased vehicle occupancy.

G. Costs

Resource efficiency measures can have economic impacts across the different stages of the value chain, which are ultimately reflected in the final price of the product. The magnitude of these costs will vary, depending on the product or process.

In some cases, resource efficiency measures can lead to increased costs, which has been identified as a barrier across multiple measures and multiple sectors.

- Cost appears as a top barrier in many of the measures under the strategy of material substitution, for example cement Measure 1 or steel Measure 2 (substitution of fossil-carbon reductants with hydrogen direct reduced iron in EAFs).
- Finally, there is an example in construction Measure 4 (reduction of construction process wastage) where the cost driver is the increased labour required to reduce over-design. The cost of labour is high compared to the relatively low cost of virgin materials.

In other cases, resource efficiency measures can reduce costs due to the reduced requirements for raw materials. This can then drive the uptake of some resource efficiency measures. This is the case for many of the measures under the strategy “Production efficiencies”, which tend to be under the control of the product manufacturers and can lead to material savings and reduced waste, both of which tend to result in reduced costs (less raw material purchased and reduced waste management fees). The cost of cement and concrete is identified as a driver of cement and concrete Measure 4 and Measure 5. The future cost of scrap is also identified as a driver of steel Measure 2 (substitution of fossil-carbon reductants with hydrogen direct reduced iron in EAFs).

Additionally, resource efficiency measures can also save operational costs throughout the product use stage. For example:

- Vehicles Measure 1 (light-weighting through material substitution) and vehicles Measure 2 (light-weighting through reduced vehicle size) identified that a driver of vehicle light-weighting is the reduced fuel costs.
- Vehicles Measure 6 (car sharing and increased vehicle occupancy) can result in lower cost for the consumers since they pay for the service, compared to the cost of ownership.

Dependencies across themes

- Theme A – Data & information with Theme B – Environmental impacts

Having better data on the environmental impacts can allow better decision-making process. This was specifically highlighted as a barrier for vehicles Measure 4 (use of biobased materials in vehicle products), where the limited understanding of environmental benefits (or otherwise) can hinder or deter greater uptake of biobased materials.

- Theme A – Data & information with Theme C – Global view

Having better data and traceability of the imported/exported products would allow better monitoring of the product characteristics and impacts of the imports and exports.

- Theme A – Data & information with Theme D – Waste hierarchy

Reliable statistics for the different end-of-life pathways are required to monitor progress and identify opportunities of moving further up the value chain.

- Theme A – Data & information with Theme F – Consumer behaviour

Consumer preferences can be influenced by the availability of decision-making data; this can take the form of lifetime cost savings. For example, buying a lighter vehicle has reduced fuel costs as shown in vehicles Measures 1 and 2, light-weighting through material substitution and light-weighting through reducing vehicle size.

- Theme A – Data & information with Theme G – Cost

Getting the right data can be costly, but not having the right data can, in turn, result in increased costs. As an example of the latter, construction Measure 1 (use of reused content in buildings) mentions as a barrier that it is both costly in time and money to try and identify what materials can be reused.

- Theme B - Environmental impacts and Theme D – Waste hierarchy

Stakeholders expressed the need to consider whole lifecycle impacts due to the trade-offs between carbon emissions and higher levels of the waste hierarchy. For example, reuse of products may require additional transport, which leads to increased carbon emissions, as discussed under construction Measures 1 (use of reused content in buildings) and 6 (reuse and recycle).

- Theme B - Environmental impacts and Theme F – Consumer behaviour

Raising consumer awareness about environmental topics can influence consumer trends, leading them to lean towards products with lower environmental footprint. Brand commitments have been identified under theme F and these are likely to influence (and be influenced by) consumer behaviour and preferences.

- Theme D – Waste hierarchy and Theme E – Training & upskilling

Many of the drivers/barriers that mentioned workforce skillset are related to the EoL measures and the need of moving up the waste hierarchy.

- Theme E – Training & upskilling and Theme G – Costs

Training and upskilling of workforces has economic impacts which are likely to be reflected in the final product costs.

6.3 Next steps

This report summarises the learnings from the first phase of the study. A second phase will be conducted over the next months with the same objectives for the next seven sectors:

- Chemicals;
- Electricals;
- Food & Drink;
- Glass;
- Paper;
- Plastics; and
- Textiles

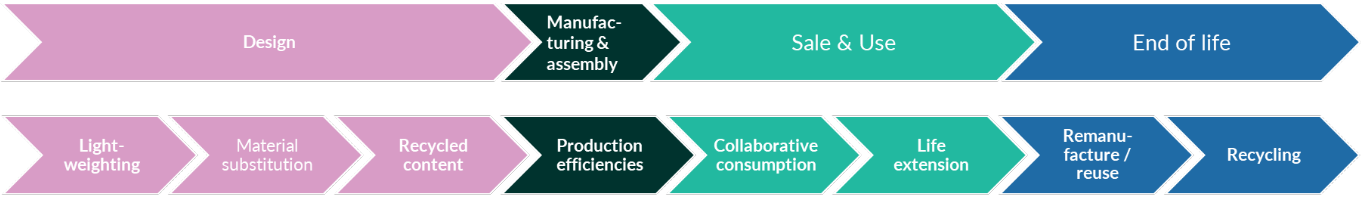
Glossary and abbreviations

BF-BOF	blast furnace – basic oxygen furnace
C&D	Construction and Demolition
CD&E	Construction, Demolition and Excavation
CKD	cement kiln dust
DRI	direct reduction of iron
EAF	Electric Arc Furnaces
EOL	End-of-life
GHG	greenhouse gas
IAS	Indicative Applicability Score
KPI	Key Performance Indicator
MRIO	multiregional input-output
RAG	red – amber – green
WLCA	whole life carbon assessment

Annex A – Mapping resource efficiency measures against lifecycle stages and resource efficiency strategies

Each identified resource efficiency measure has been mapped against a **framework** that shows four lifecycle stages and seven resource efficiency strategies.

Figure 8: Framework mapping lifecycle stages and resource efficiency strategies



- In the design stage of the lifecycle many decisions are made about the product, which have impacts until the end of life. Three key resource efficiency strategies are identified:
  - Light-weighting refers to reducing the mass of the final product, which leads to resource efficiency savings in terms of material use avoided.
  - Material substitution has been discussed earlier.
  - Recycled content (also named 'use of secondary raw materials') refers to displacing virgin raw materials with material that had reached its end of life.
- After the product has been designed, it needs to be manufactured, and in some sectors, further assembled. Depending on the sector, there can be several manufacturing and assembly steps, for example cement into concrete and concrete into a building/infrastructure, or iron ore into steel and steel into a vehicle component which is further assembled into a vehicle.
- The identified resource efficiency strategy is 'production efficiencies' which lead to reduced waste in this phase of the lifecycle and thus reduced material requirements.
- Once the product is manufactured, it is sold and then used by the consumer/user. This phase can have differing lengths. There are two identified strategies:
  - Collaborative consumption can lead to higher utilisation of the products and potentially reduced consumption, which leads to resource efficiency. This can be achieved through rental business models but also product sharing models.
  - Life extension refers to the different techniques applied by consumers or manufacturers or other actors of the value chain that can extend the usable lifetime of the product. This can take the form of repair, retrofit or refurbishment. Where lifetime extension can avoid or delay consumption of a new product, it leads to resource efficiency.

- Finally, once the product has reached the end of its (first) life, there are several strategies that can be applied to continue getting value of the product and delay the stage where it is disposed of. For simplicity, the strategies have been grouped in two:
    - Remanufacture or reuse keeps the product as a product and can provide a second (mor more) life for the product, usually in the hands of a different user. If this new life displaces or delays the consumption of a new item, it leads to resource efficiency.
    - Recycling refers to the process of turning the EOL product into a new material, which is not necessarily the same product as it was originally.

This framework is defined at a high-level to ensure that it fits the four sectors of phase 1 (and potentially the seven sectors of phase 2). Therefore, it is not meant to be a comprehensive description of each sector but an instrument that will allow comparing the resource efficiency measures across the sectors.

This publication is available from: www.gov.uk/government/publications/unlocking-resource-efficiency

If you need a version of this document in a more accessible format, please email alt.formats@energysecurity.gov.uk. Please tell us what format you need. It will help us if you say what assistive technology you use.